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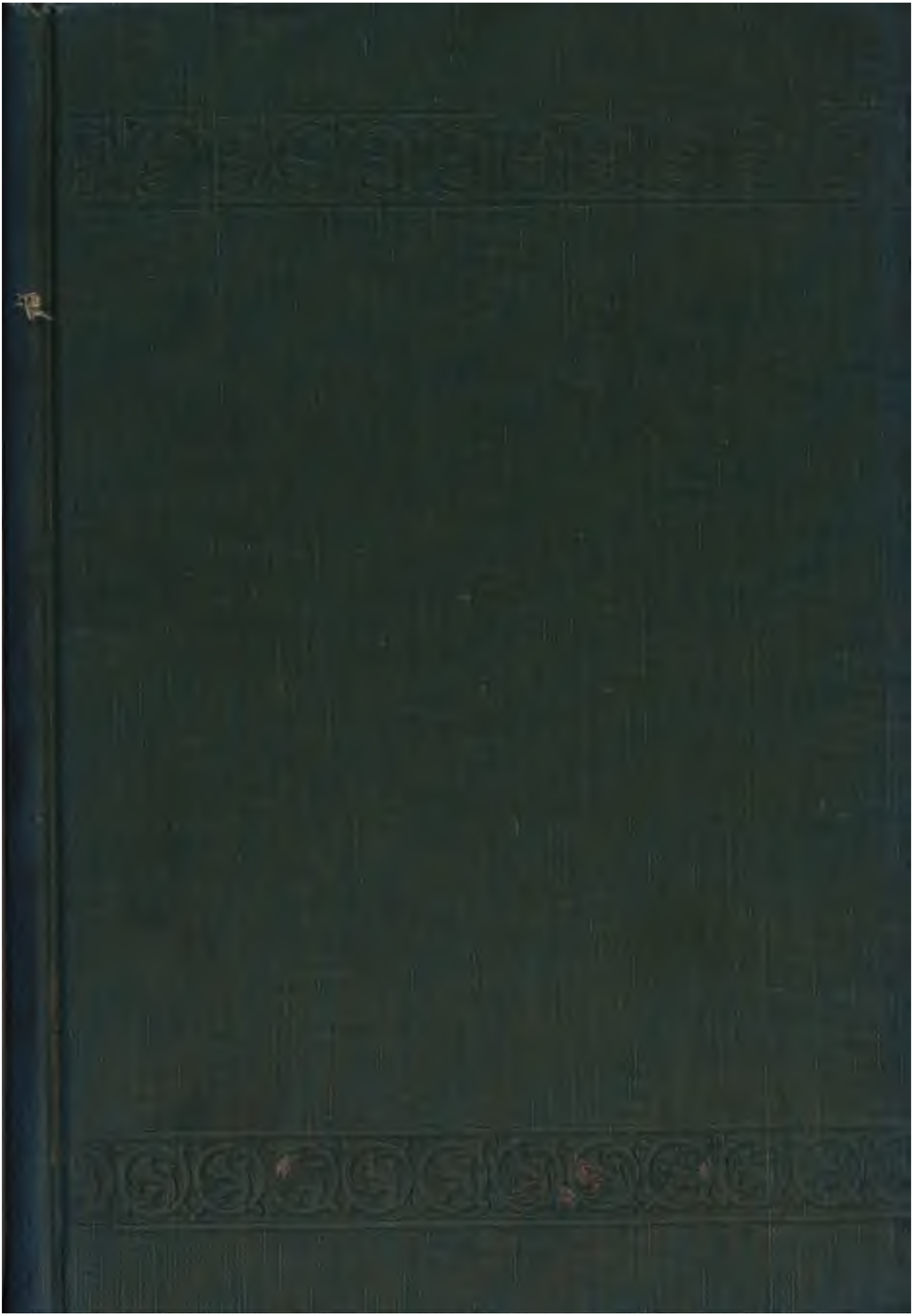

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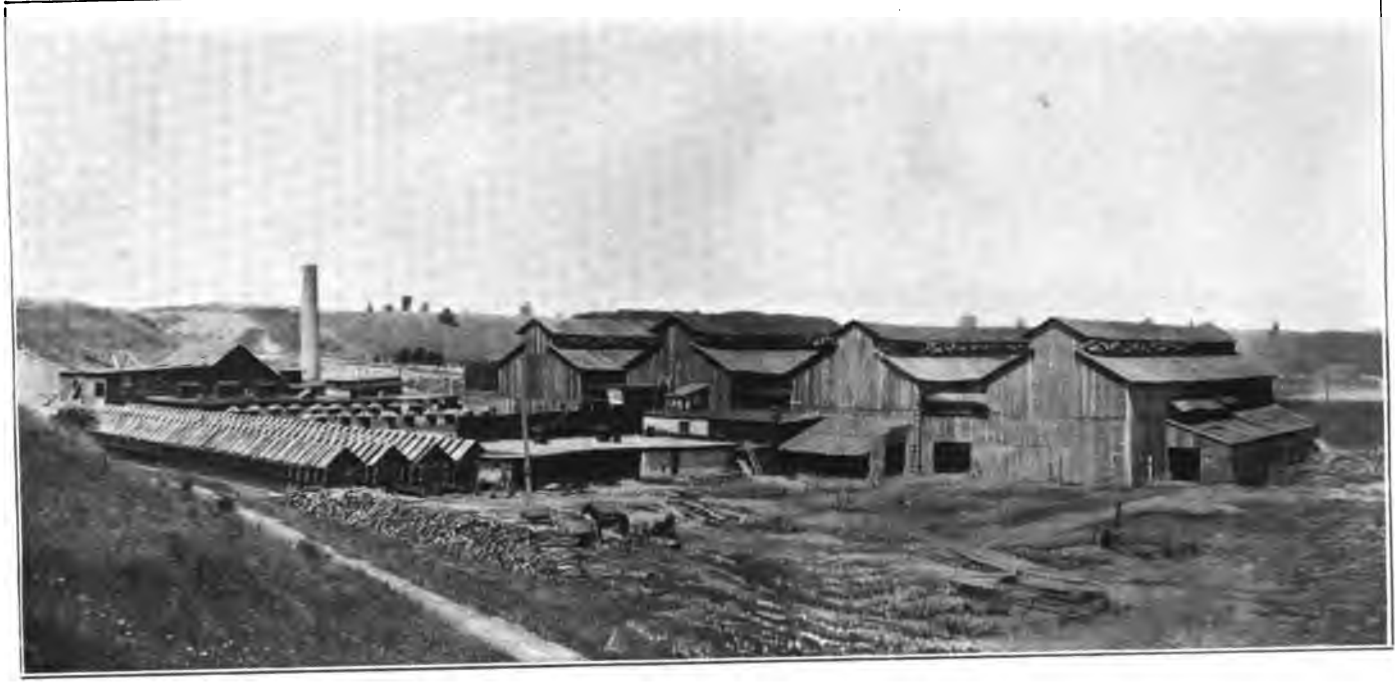

General view of plant of Manitowoc Clay Mfg. Co., Manitowoc.

WISCONSIN GEOLOGICAL AND NATURAL HISTORY SURVEY

E. A. BIRGE, Ph. D., Sc. D., Director

BULLETIN NO. XV ECONOMIC SERIES NO. 10

THE
CLAYS OF WISCONSIN
And Their Uses

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BY

HEINRICH RIES, PH. D.

WITH A REPORT ON MOLDING SANDS

BY

H. RIES AND F. L. GALLUP.

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PREFACE.

In 1900 the Wisconsin Geological and Natural History Survey issued a report on the clays and clay industries of Wisconsin by Dr. E. R. Buckley. In this bulletin the geology of the clays and the individual plants were discussed in some detail, and a large number of clay analyses were made on samples from different localities in the state.

Dr. Buckley's bulletin was published as Bulletin No. VII, Part 1, and it was intended to follow this by Part 2, which should contain the result of the physical and other tests on brick which were in progress but not completed when the bulletin was issued. Shortly after, Dr. Buckley resigned from the Wisconsin Geological Survey and accepted the position of State Geologist of Missouri, and the completion of the report, was, therefore, rendered impossible. The present bulletin gives special attention to those points in the investigation of the clays which were left untouched by the preceding report. It is, however, a wholly independent report and is, therefore, issued as an independent bulletin and not as the promised second part of Bulletin No. VII.

The writer, assisted by Mr. F. L. Gallup spent the summer of 1904 in the field studying the various deposits and plants, and collecting a number of samples for the laboratory investigation. Nearly all of these samples were carefully taken either by the author of the present bulletin, or by his assistant, and shipped to the laboratory for a careful study of their physical properties, with a view not only of determining their possible range of applications, but also for the purpose of supplying information to clay workers seeking information regarding them.

A second line of work has been the collection of a series of brick samples from most of the brickyards in the state for the purpose of test, and the results of these tests, given in Chapter V, have brought out a number of interesting and valuable facts.

In response to many questions asked by the Wisconsin clayworkers, a chapter on the structure, chemical, and physical properties of clays has also been incorporated in the report. Although a number of analyses were made for the earlier bulletin, it was found desirable to make a few additional ones, for the present paper.

This statement is made in order to answer the numerous inquiries which the Survey has received from persons desiring the second part of Bulletin No. VII.

The writer hopes that the investigation of clays, which is reported in this bulletin, wll aid in the development of the clay industries of Wisconsin and will help to increase the variety of the clay products. In 1905 the value of the products of the clay-working industries of the state was $1,382,115. More than 90% of this value was in common brick. As the price of lumber rises, the demand for clay products in Wisconsin is certain to increase, especially for the finer varieties. Many of these can be supplied from the local clays of the state if their manufacture is taken up and placed upon a commercial basis. The tests of clays here reported should aid in the selection of suitable localities and in the finding of suitable material for the development of the industry.

The writer takes pleasure in here acknowledging the many courtesies received from the clay manufacturers in all parts of the state, and special acknowledgments are due to Dr. E. A. Birge, Director of the Survey, Mr. F. L. Gallup, who served as assistant throughout the work, to Dr. S. Weidman, of the Survey, Professor Victor Lenher of the University of Wisconsin who made most of the analyses given in the following pages, Professor U. S. Grant of Northwestern University, Mr. F. H. Merrill of Portage City, and Mr. Kirby Thomas of Superior.

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THE CLAYS OF WISCONSIN AND THEIR USES.

CHAPTER I.

ORIGIN AND PROPERTIES OF CLAY.

In this chapter it is proposed to discuss the general structural features and physical and chemical properties of clays, as well as to point out briefly the practical bearing of these facts, which frequently exert an important influence on the method of mining, manufacture, and applications of the material.

Clay defined. It would seem to some that a definition of this material is hardly necessary, since its two important properties, viz., plasticity when wet, and change to a rock-like condition when burned are familiar to all, and yet such a definition, if made in detail, often serves to point out hitherto unobserved characteristics. Clay may therefore be defined as a more or less plastic mixture of small mineral particles and organic matter varying in size from those under one thousandth of an inch in diameter up to sand grains clearly visible to the naked eye, and including a variety of mineral species in all stages of decay. These mineral compounds consist chemically of oxides, carbonates, silicates, hydroxides, etc. The effect of heat is to decompose many of these, drive off volatile elements, and cause the clay to fuse to a hard mass.

Clay, by an increase in the percentage of certain minerals may pass into other rock types, this change being accompanied by the loss of its more characteristic physical features. Thus with an increase in silica a clay will pass into sand, or in a similar manner it may grade into marl by an increase in its lime carbonate contents. Curiously enough the percentage of sand or lime carbonate often reaches considerable proportions before the plastic qualities of the clay disappear.

FORMATION OF CLAY. Clay deposits may be grouped according to their origin as primary and secondary, and both kinds are of importance in Wisconsin.

PRIMARY OR RESIDUAL CLAYS. These result from the demonposition of other rocks, especially those containing feldspar, but they may also be formed from other types, even serpentine with no feldspathic minerals, yielding sometimes a very tough plastic clay.

The formation of residual clay begins with the disintegration of the rock mass by frost and sun. This opens up a path for the soil waters which attack many of the mineral grains in the rocks, breaking them down to a clayey mass, but certain minerals like quartz and white mica are affected but little or not at all and may remain untouched even after all the other minerals in the rock have yielded to weathering influences. The gritty character of many of the clays in the residual area of Wisconsin is due to an abundance of angular grains and fragments of quartz.

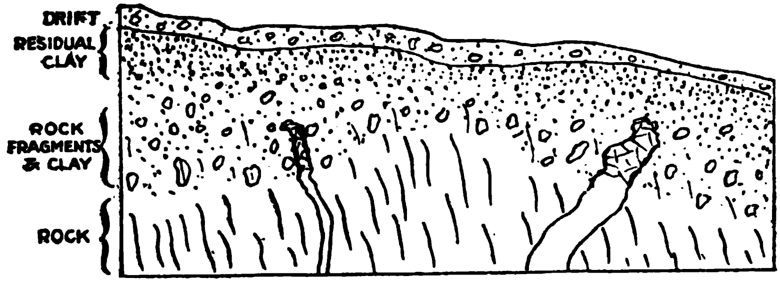

FIG. 1.—Section showing transition from residual clay into parent rock.

Since residual clays are the result of weathering processes, which begin at the surface and work their way into the rock mass, those portions nearest the surface will be most advanced in their decomposition, and there will be a gradual transition from the clay above into the parent rock below (Fig. 1). Residual clays vary in depth from place to place and even in the same pit the rock surface underlying the clay may rise and fall, being within four feet of the surface at one point, and fifteen or twenty feet below it at another point not fifty feet distant. On this account it is of the highest importance to prospect such a deposit by careful boring, before attempting to work it.

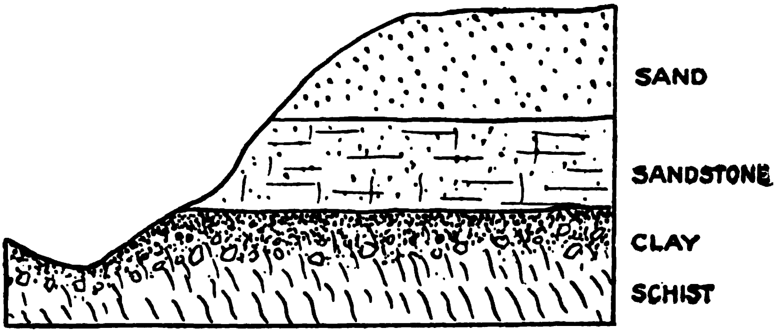

FIG. 2.—Section showing residual clay covered by Potsdam sandstone. Eau Claire River east of Eau Claire.

The residual clays of Wisconsin are found under conditions differing somewhat from those in other states. Formed in early geological times, they were later covered by a protective layer of sandstone, which has also served to conceal them, and they are now exposed either where this sandstone has been worn away, or where the streams have cut down through it (Fig. 2), thus exposing them, on the valley slopes, or sides of the channel.

Residual clays may show almost any color, but red and brown are perhaps the commonest. When free from iron oxide or nearly so the material is white, and this variety is termed *kaolin*. So far as the writer has been able to ascertain, no commercially valuable deposits of true kaolin have thus far been discovered in Wisconsin.

Where unprotected, residual clays are eroded easily by rain or surface streams especially if the deposits are situated on ridges or steep slopes. Consequently, other things being equal, the thickest deposits are to be sought for on surfaces of little or no slope, or in depressions.

SECONDARY OR SEDIMENTARY CLAYS. These have been derived originally from residual clays, whose particles have been washed down into streams and carried out to seas, or lakes where they have been deposited as sediment on the bottom. Mingled with the clay particles there is a variable amount of rock fragments or sand grains, thus producing a somewhat heterogeneous mixture, which however possesses the plastic qualities of clay.

These clayey sediments differ from residual ones in being stratified. They have accumulated slowly, one layer on top of another, successive beds sometimes being alike or just as often of the most diverse character. Any bed or series of beds may also and often does show horizontal variations. One of the best examples of this is seen in the appearance and disappearance of sand layers in a clay deposit. Thus at one time there may be a bed of sand or sandy clay two or three feet thick in the middle of the clay bed, but as the working face is pushed ahead, this becomes thinner and thinner and finally disappears. Sometimes another one may take its place. Stratified clays are often of great thickness, much thicker than the residual clays.

Stratified or sedimentary clays can be classified according to their mode or origin into, *marine, estuarine, boulder, lake, flood plain* or *terrace*, and *glacial clays.*

Marine clays are those deposited on the ocean bottom where the water is quiet, and are often of great extent and thickness. The only deposits of this type, found in Wisconsin, are (1) the Maquoketa shale of Grant and Lafayette counties, which is simply part of an extensive deposit which extends southward into Illinois and westward into Iowa, and (2) the Cincinnati shale found in southeastern Wisconsin. Their qualities seem to be quite uniform over a large area.

Estuarine clays are those laid down in shallow arms of a sea, of either continental or inland character, and areally the deposits are generally long and narrow. These clays are often finely laminated and in the Wisconsin deposits of this type show very little sand. They commonly fill shallow depressions surrounded by sand hills (Fig. 3). Those of Whitewater, Edgerton, Jefferson and New London are all excellent examples of this type.

Lake clays include those which have been formed in lakes. Where the lake was small the clay deposit is usually basin shaped, but where large this character is not observable. Small lake deposits are found on the surface in many portions of the glaciated area of the state, but the most extensive are those found along lakes Michigan and Superior. These have been deposited during a former extension of the Great Lakes, and are extensively distributed through the eastern and northern portions of the state.

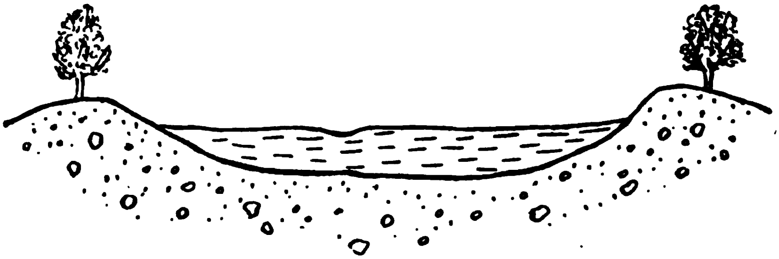

FIG. 3.—Section across Wisconsin clay deposit of estuarine type.

Lake clays are usually of high plasticity, and of low purity, and in Wisconsin are mostly cream burning.

Flood plain or terrace clays, are clays, usually of silty character, deposited by rivers during periods of overflow. They underlie the flat terraces or flood plains bordering many of the larger rivers and sometimes smaller ones. Clays of this type are liable to show both vertical and horizontal variation. Very few are worked in Wisconsin.

Boulder clays are tough, gritty clays, often of stony character. They represent rock flour, the product of glacial grinding, and are mostly too stony for use. Very few deposits of this type are worked in Wisconsin.

CHANGES IN CLAY DEPOSITS SUBSEQUENT TO THEIR FORMATION. Both residual clays and stratified or sedimentary clays may undergo secondary changes of either physical or chemical character subsequent to their formation. Only those affecting the Wisconsin clays will be mentioned, and nearly all are directly or indirectly, the result of weathering. They may include change of color, leaching, softening, or consolidation.

Color changes. Nearly all portions of a clay deposit, which have been exposed to the weather for some time show various tints of yellow or brown, the common color of the unweathered clay being gray, grayish brown or reddish brown. The colors produced by weathering, are caused by a rusting out or oxidation of the iron oxide which the clay contains, the depth to which the weathering agents have penetrated the clay being often indicated by the extent of oxidation of the iron. This shows great irregularity, being greatest along joint planes, or plant roots, and least where the clay is solid; where the clay is overlain by sand or other material, this frequently serves as a protective covering for the clay underneath. Clays of black color due to carbonaceous matter, are sometimes bleached on the surface due to the oxidation of the carbon to carbon dioxide.

Changes of color, caused by weathering, can be distinguished from variations in color of primary character by the fact that the former are most intense at the surface and shade off gradually towards the interior, whether this direction be vertical or horizontal.

Leaching. Most clays contain at least a small quantity of mineral matter soluble in water, and a still larger amount soluble in waters containing acids. More or less surface water filters into a clay deposit, passing first through the soil where it abstracts a small quantity of organic or carbonic acids, which materially increase its solvent power. These weak acid solutions are specially active in dissolving the lime carbonate from the upper layers of calcareous clays and transferring them to the lower beds, so that the upper 2 or 3 feet of a calcareous clay bank often show considerably less lime carbonate than the underlying strata, and may be even red burning.

Softening. All clays, unless covered by heavy overburden are liable to soften or disintegrate on their outcrops, as the result of weathering, especially frost action. In some instances the softening may be caused by the removal of soluble mineral matter which had cemented the particles together.

Many clay manufacturers take advantage of this natural process of softening and spread out the clay so that it can be exposed to frost, rain and sun, but none of the Wisconsin brick manufacturers do this.

Concretions are irregular nodules of limonite, siderite, or lime carbonate, which form in many clays, around a nucleus of pebbles or grains of sand. They are generally about walnut size, but occasionally are much larger. These concretions, when met in the calcareous clays of Wisconsin, are similar to limestone pebbles in their effect, and unless screened out or crushed often cause the brick to split in drying and after burning.

Shales. These are consolidated clays, the hardening having been accomplished either by pressure of overlying sediments, or at times by a cementing of the grains, or both. Most shales will on grinding and mixing with water show as much plasticity as surface clays. The only true shale of value to the clay worker in Wisconsin is the Maquoketa or Cincinnati shale.

THE EXAMINATION OF CLAY PROPERTIES. Much expense is often saved by properly exploiting a clay property before erecting a plant, such examinations, coupled with laboratory investigations or tests made at a factory, often preventing needless expenditure of money in the event of the clay proving unsuited to the uses to which it is contemplated putting it.

It is never safe to pass final judgment on a clay from an examination of the outcrops alone, since the section oftentimes varies in a few feet.

The presence of a clay bed can often be established from an examination of the soil, but better still from a careful inspection of the sides of any natural or artificial cuttings such as ravines, and railroad or wagon road cuts. Well records of any sort may likewise give data of value. All of these, should however be supplemented by a careful examination of the property, made either by boring a sufficient number of holes with a large auger, or by sinking test pits. Where time and money are available, the latter is preferable, and does not take much extra time, as one man can sink a pit 3x6 feet to a depth of 10 feet in about three hours.

THE CHEMICAL AND MINERALOGICAL COMPOSITION OF CLAYS.

The composition of clay is of some practical importance, as it stands in close relation to its physical character, and the analysis when properly interpreted can at times be used as a partial guide towards the probable physical behavior of the substance. Since the chemical composition of the clay depends on the mineral species present in it, it may be well to refer to these first.

MINERALS IN CLAY. The minerals most frequently found in clays are quartz, feldspar, calcite, dolomite, gypsum, mica, pyrite, iron ores, hornblende, and rutile. All of these with the exception of quartz and mica are as a rule present in such small grains that they are not visible to the naked eye, and can be detected only with a microscope. Their general characteristics and effects are referred to below.

Quartz or silica is absent from few clays, whether residual or sedimentary, forming most of the sand grains from those clearly visible to the naked eye, down to those forming the finest grit, detectable only with the teeth or microscope. Most of the sand and silt in the Wisconsin clays, therefore, consist of it.

Quartz exerts a strong influence on the physical behavior of clays, for since it may be regarded as a sandy impurity, an increasing amount of it lessens the air shrinkage, decreases the plasticity, and renders the body more porous in burning.

Alone, quartz is highly refractory, and its presence in low grade clays tends to raise their fire-resisting qualities, but when clays are heated to high temperatures, quartz reverses its behavior and fluxes with the alumina, consequently in low or medium grade clays a slight excess of quartz is beneficial for their fire-resisting qualities, but in fire clays it is detrimental.

Feldspar, which is a complex silicate of alumina with either potash, soda, or lime, is no doubt present in many clays, but the grains are rarely large enough to be observable by the naked eye, for the reason that the mineral is less resistant to the weather than quartz, and hence breaks down easily into fine grains, which rapidly decay to clay.

If present its effects on the plasticity, and air shrinkage is so far as known, much like that of quartz sand. It will also tend to reduce the fire shrinkage of a clay up to its fusion point, or point of fluxing with other more easily fusible elements in the clay. It is by no means as refractory as quartz, fusing at a temperature of about 1180° C, the exact fusion point depending on the feldspar species present.

On account of its fusibility and usual freedom from iron oxide feldspar is regarded as an important fluxing element by whiteware manufacturers.

Mica, which is another silicate of complex composition, consists of silica and alumina, with other bases. There are two common species, known respectively as muscovite or white mica and biotite or black mica. The former, which is a compound of silica, alumina, and potash is whitish in color, and decays very slowly when exposed to the weather, while the latter which is a compound of silica, alumina, magnesia, and iron, is much less resistant and decomposes more readily. On this account muscovite is the mica species usually recognizable in clays, and is one of the very few minerals that can be detected in very small grains, for the bright shining scales of this mineral are quite prominent and readily catch the eye.

Of the Wisconsin clays examined, the residual clays contain the most mica, while in the lake and estuarine clays it is comparatively scarce.

Iron ores. Under this caption is included a series of iron compounds, which are the same as those worked for iron when in sufficiently concentrated form, but in clays they are present in too small amount to answer for this purpose. They include the four mineral species, limonite, hematite, siderite, and magnetite.

The first of these is present in all clays stained brown and yellow. The second is no doubt present in many of the red clays, while the third occurs probably in calcareous clays, and the fourth is doubtfully present in some of the residual clays.

Few of these iron compounds are as a rule present in granular form, but occur as a film of cement around the other mineral grains. Some, like the limonite, may assume a gelatinous or colloidal condition, but this is difficult of proof. In a few instances both the limonite and siderite may form concretionary masses.

The main fact to be remembered is, that some form of iron oxide is also invariably present in clays, though in varying amounts as can be seen from the analyses in this report.

Other iron-bearing minerals. Pyrite, the sulphide of iron, a yellow metallic mineral when fresh, is not uncommon in some clays, but none was observed in any of the Wisconsin deposits.

Iron also occurs as an ingredient of some silicate minerals, such as biotite mica, garnet, or hornblende, and these are present in small quantities in the residual clays, as well as possibly in some others.

Effects of iron. If in granular form, the iron would have much the same effect as sand in the unburned clay.

If as a film or cement, it would act as a coloring agent, the limonite and hematite being important in this respect and coloring the clay yellow, brown, or red. This strong coloring effect is noticed chiefly in the residual clays, some of which contain over 15 per cent iron oxide. This point is referred to again in more detail. In burning the iron aids the fusion of the clay, and also serves to color it buff or red, depending on the amount present.

Calcite. This mineral consists of carbonate of lime, and is especially abundant in the lake and estuarine clays of Wisconsin, as well as in some of those of the glacial type. The Maquoketa shales also contain it, though to a less amount. It can be easily detected for it dissolves rapidly in weak acids and effervesces violently upon the application of a drop of muriatic acid or even vinegar. It is fortunate that its presence can be so easily determined, for it is rarely found in sufficiently large grains to permit its identification with the naked eye. The concretions found in many clays are largely composed of lime carbonate.

Dolomite, the double carbonate of lime and magnesia, occurs no doubt in many of the surface clays of Wisconsin, judging from the large amount of magnesium carbonate which they contain, but the grains are always of microscopic size.

Gypsum, the hydrous sulphate of lime, may be present in many clays, but was not seen in any of the Wisconsin ones, except on microscopic examination.

Hornblende, pyroxene, and garnet are all silicate minerals of complex composition, and occur in many of the residual clays in very small grains. Both are easily fusible and weather readily, on account of the iron oxide which they contain, and, therefore impart a deep red color to those clays formed from rocks in which they are a prominent constituent. The residual clay outcropping on the Wisconsin river southwest of Medford is a good example of this.

THE CHEMICAL ANALYSIS OF CLAYS. There are two methods of quantitatively analyzing clays, the one being termed the ultimate analysis and the other the rational analysis.

The ultimate analysis. In this method of analysis, which is the one usually employed the various ingredients of a clay are considered to exist as oxides, although they may really be present in much more complex form. Thus, for example, calcium carbonate ($CaCO_3$), if it were present, is not expressed as such, but instead it is considered as broken up into carbon dioxide

(CO_2) and lime (CaO), with the percentage of each given separately. The sum of these two percentages would, however, be equal to the amount of lime carbonate present. While the ultimate analysis, therefore, fails to indicate definitely what compounds are present in the clay, still there are many facts to be gained from it.

The ultimate analysis of a clay might be expressed as follows:

		Silica	(SiO_2)
		Alumina	(Al_2O_3)
Fluxing impurities..		Ferric oxide	(Fe_2O_3)
		Lime	(CaO)
		Magnesia	(MgO)
	Alkalies........	Potash	(K_2O)
		Soda	(Na_2O)
		Titanic oxide	(TiO_2)
		Sulphur trioxide	(SO_3)
		Carbon dioxide	(CO_2)
		Water	(H_2O)

In many analyses, the first seven of these and the last one are usually determined. The percentage of carbon dioxide is usually small, and commonly remains undetermined, except in very calcareous clays. Titanic oxide is rarely looked for, except in fire clays, and even here its presence is frequently neglected. Since the sulphur trioxide, carbon dioxide, and water are volatile at a red heat, they are often determined collectively and expressed as "Loss on ignition." If carbonaceous matter, such as lignite, is present this also, will burn off at redness. To separate these four, special methods are necessary, but they are rarely applied, and, in fact, are not very necessary, except in calcareous clays, or black clays. The loss on ignition in the majority of dry clays is chiefly chemically combined water. The ferric oxide, lime, magnesia, potash, and soda are termed the fluxing impurities, and their effects are discussed under the head of Iron, Lime, Magnesia, etc., and also under Fusibility.

All clays contain a small but variable amount of moisture in their pores, which can be driven off at 100° C. (212° F.). In order, therefore, to obtain results that can be easily compared it is desirable to make the analysis on a moisture-free sample, which has been previously dried in a hot-air bath. This is unfortunately not universally done.

The facts obtainable from the ultimate analysis of a clay are the following:

1. The purity of the clay, showing the proportions of silica, alumina, combined water, and fluxing impurities. High-grade clays show a percentage of silica, alumina, and water, approaching quite closely to those of kaolinite.

2. The refractoriness of the clay, for, other things being equal, the greater the total sum of fluxing impurities, the more fusible the clay.

3. The color to which the clay burns. This may be judged approximately, for clays with several per cent or more of ferric oxide will burn red, provided the iron is evenly and finely distributed in the clay, and there is no excess of lime. The above conditions will be affected by a reducing atmosphere in burning, or the presence of sulphur in the fire gases.

4. The quantity of water. Clays with a large amount of chemically combined water sometimes exhibit a tendency to crack in burning, and may also show high shrinkage. If kaolinite is the only mineral present containing chemically combined water, the percentage of the latter will be approximately one-third that of the percentage of alumina, but if the clay contains much limonite or hydrous silica the percentage of chemically combined water may be much higher.

5. Excess of silica. A large excess of silica indicates a sandy clay, and if much is present in the analysis of a fire clay, it indicates low refractoriness.

6. The quantity of organic matter. If this is determined separately, and it is present to the extent of several per cent, it would require slow burning if the clay was dense.

7. The presence of several per cent. of both lime (CaO) and carbon dioxide (CO_2) in the clay indicates that it is quite calcareous.

These are the main points determinable from the ultimate analysis.

Analyses of several different types of clay.

	1	2	3	4	5	6
Silica (SiO_2)	46.3	48.26	61.6	60.44	32.48	73.08
Alumina (Al_2O_3)	39.8	37.64	28.38	19.74	7.31	11.58
Ferric oxide (Fe_2O_3)	....	.46	.52	6.23	4.37	4.11
Lime (CaO)	....	.06	.46	.40	18.44	.84
Magnesia (MgO)	....	tr.	.36	2.22	7.18	.52
Potash (K_2O)	.....	1.56	....	4.03	2.01	2.31
Soda (Na_2O)	.....		....	1.89	.48	2.75
Water (H_2O)	13.9	12.02	....	....	....	....
Loss of ignition	....	....	5.08	5.66	27.70	5.36
Titanic oxide (TiO_2)	....	....	3.60	.06	.12	.09
Carbon dioxide (CO_2)	....	....	....	....	*	....

* Included under ignition.

1. Kaolinite.
2. Kaolin or china clay. Approaches closely to kaolinite in composition.
3. A fire clay, Woodbridge, N. J. Low percentage of fluxing impurities.
4. A red-burning clay. Note high iron and low lime percentage.
5. A calcareous clay. Note high lime percentage.
6. A very sandy clay. Note high silica percentage.

Rational analysis. This method has for its object the determination of the percentage of different mineral compounds present, such as quartz, feldspar, kaolinite, etc., and affords a better conception of the true character of the material. Where the clay contains only the three mineral ingredients mentioned above, the execution of the rational analysis is comparatively simple, but where other minerals are present, as in low grade clays, its manipulation is attended with more difficulty. However the rational analysis is applied usually only to the better grades of clay, such as kaolins to be used for china ware, and there it is an important aid to the potter who understands its use.

The rational composition of clay can be determined from its ultimate analysis, but it involves complex calculations, and the results obtained in this manner are less accurate, than if the rational composition is determined in the usual way.

CHEMICAL COMPOUNDS IN CLAY AND THEIR EFFECTS. In explaining above the mode of expressing the ultimate composition of a clay, it was pointed out that a number of compounds were usually present, and that some of these influence the character of the clay to a marked degree.

The effects of these should be discussed next.

Silica. Silica is usually present in clays in the form of quartz, but in addition to this it may be present as an ingredient of various silicate minerals, of which the most important are the minerals kaolinite, feldspar, mica, or hornblende. The exact form of combination of the silica is not usually regarded in the ultimate analysis, although sometimes *free* and *combined* silica are referred to, the former covering all silica except that contained in kaolinite. Such a division is misleading, and a better practice is to use the term sand to include quartz, and silicate minerals other than kaolinite, which are not decomposable by sulphuric acid. In most analyses, the total silica alone is given.

Clays vary widely in their silica contents, and as fair examples of extremes we may take the calcareous clay from Whitewater with 32.48 per cent of silica, and the loess clay from Arcadia with 73.08 per cent of silica.

With the exception of kaolinite, all of the silica-bearing minerals are rather sandy in their nature. A high percentage of silica generally indicates a sandy or silty clay, and a large quantity will thus tend to reduce the air and fire shrinkage as well as plasticity, the effect increasing with the size of the silica grains.

Iron oxide. This is one of the commonest ingredients of clays, and few are absolutely free from it, although the amount present, as in some china clays, may be but a trace. A number of minerals may serve as sources of iron oxide in clays, three of which, viz., limonite, hematite, and magnetite are themselves oxides, while in the others the iron is held in combination with other elements, forming silicates, sulphides, or carbonates. This latter class yield up iron oxide only after decomposition.

Iron exerts a wide spread effect as a coloring agent in both raw and burned clay. In the raw clay it produces yellow, brown, or red colors from oxides such as limonite and hematite, or green colors due to silicates. The carbonate (siderite) and the sulphide (pyrite) might if present in sufficient quantity and in fine form produce a gray coloration. The intensity of the color cannot be taken as an indication of the amount of iron present, for it requires a much smaller amount of iron to produce a given shade in a sandy clay than in one free from sand.

But, even several per cent of iron oxide may not be noticeable, if the clay contains much carbonaceous matter, because this keeps the iron oxide in a reduced form, in which condition its colors are less brilliant, and in addition the carbonaceous matter often masks the iron color. Again the maximum coloring effect is obtained by an even distribution of the iron oxide in the clay, rather than by its segregation into lumps or patches.

The coloring effects of iron oxide in burned clay will depend on 1. the amount of iron in the clay, 2. the temperature of burning, 3. condition of iron oxide and 4. the condition of the kiln atmosphere.

1. Clay free from iron oxide, or nearly so, burns white. As small a quantity as 1 per cent, may impart a slight yellowish tint to the clay in burning, while 2 to 3 per cent yield buff colors, and above this red shades.

2. In any given clay, the intensity of color, deepens with an increase in temperature, a red-burning clay passing through pink, pale red, red, deep red, and reddish purple, if burned at successively higher temperatures.

3. Two forms of iron oxide are recognized, viz., the ferrous oxide (FeO) and the ferric oxide (Fe_2O_3). In the former one part of iron is united with one part of oxygen, but in the latter one of iron is combined with one and a half parts of oxygen.

The ferric oxide therefore, contains more oxygen per unit of iron than the ferrous salt, and is said to represent a higher stage of oxidation. Limonite for example represents the ferric condition of iron for its composition is $Fe_2O_3+H_2O$. Siderite, the carbonate of iron, has the formula FeO, CO_2, and here the iron is in the ferrous stage.

Under favorable conditions, iron passes rather readily from the ferrous to the ferric condition and vice versa. Thus if there is a deficit of oxygen in the interior of the kiln for proper combustion of the carbon, the fuel will steal it from the iron oxides in the clay, and reduce them to the ferrous state. On the other hand if there is more than enough air in the kiln to support combustion, all the iron oxide in the clay gets changed tc the ferric form and the brightest tints obtainable from the amount of iron in the clay, are formed. Smoky fires, for instance produce deoxidizing results. Ferric oxides yield buff, red, or brown colors, while ferrous oxides produce blue or black tints.

The bricks made from clay containing carbonaceous matter sometimes show a black core. The reason for this is as follows: In the firing of such a clay, the carbonaceous matter is burned off wholly or in part, but this process requires oxygen, which comes either from the kiln fire or the ferric oxide in the clay. Consequently as long as carbonaceous matter remains in the brick, the iron oxide will be kept in a ferrous form. When it finally does begin to oxidize, the change begins from the surface and works towards the center of the brick, but owing to the shrinkage of the clay the body may have become too dense to allow the oxygen to enter, and there consequently remains a black or bluish black core of ferrous iron. It should be here stated that the iron is not ferrous iron alone, but this in combination with at least silica, giving probably a complex ferrous silicate. Some of the bluish black color of the core may also be due to unconsumed carbon.

4. Since the stage of oxidation of the iron is dependent on the quantity of air it receives in burning, the condition of the kiln atmosphere is of great importance. If there is a deficiency of oxygen in the kiln, the fire is said to be *reducing*. If on the contrary there is an excess of oxygen, the fire is said to be *oxidizing*. These various conditions are often used by the manufacturer to produce certain shades or color effects in the ware.

Iron oxide is also a fluxing impurity, lowering the fusing point of a clay, and this effect will be more pronounced if the iron is in a ferrous condition or if silica is present. A low iron content is, therefore, desirable in refractory clays. Fire clays commonly show under 3 per cent, and brick clays often contain 5 or more per cent.

Lime. Lime is found in many clays, and is abundant in many of the Wisconsin ones. While a number of minerals may serve as the source of it, the chief ones in the Wisconsin clays are the carbonates, calcite ($CaCO_3$) and dolomite ($(Ca\ Mg)\ CO_3$). Whenever the ultimate analysis of a clay shows several per cent of lime (CaO) it is usually there as an ingredient of lime carbonate ($CaCO_3$), and in such cases its presence can be easily detected by putting drop of muriatic acid or vinegar on the clay.

PLATE II.

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When this compound is present it is mostly of very finely divided character, but sometimes forms limestone pebbles, or concretions.

Action of lime carbonate in clays. When clays containing lime carbonate are burned they lose not only their chemically combined water, but also their carbonic acid gas, which leaves the clay in a very porous condition, it remaining so until the clay is vitrified. This fact is well shown by the high absorption of the cream-burning samples tested, as well as by the absorption tests made on the cream-colored bricks.

If the burning is carried only far enough to drive off the carbonic acid gas, the result will be that the quicklime thus formed will absorb moisture from the air and slake. No injury may result from this if the lime is in a finely divided condition and uniformly distributed through the brick, but, if, on the contrary it is present in the form of lumps, the slaking and accompanying swelling of these may split the brick.

If, however, the temperature is raised higher than is required simply to drive off the carbon dioxide, and if some of the mineral particles soften, a chemical reaction begins between the lime, iron, and some of the silica and alumina of the clay, the result being the formation within the clay of a new silicate compound of very complex composition. The effects of this combination are several. In the first place, the lime tends to destroy the red coloring of the iron and impart instead a buff color to the burned clay. This bleaching action is most marked when the percentage of lime is three times that of the iron.

Aside from this lime carbonate also affects the fire shrinkage and fusibility of a clay. Calcareous or limy clays do not shrink steadily when burned. On the contrary they swell slightly in the early stages of firing. It is found in firing the continuous kilns at Milwaukee that a chamber of bricks set about 30 courses high increases as much as two and a half to three inches in height in the early stages of firing, and then shrinks again to its original volume, the latter being reached at about the fusion point of cone 3, at which point the burning is stopped. If the clay is heated still farther its shrinkage is found to be very low until its point of vitrification is almost reached when the fire shrinkage shows a sudden and large increase. This is followed by a rapid softening of the clay. Indeed, calcareous clays soften so rapidly that the points of incipient fusion and viscosity are often within 41.6 C. (76 F.) of each other. This rapid softening of calcareous clays is one of the main objections to their use for vitrified ware.

One peculiar feature about many of the Wisconsin calcareous clays is their higher fusion point as compared with those from many from other states, not a few becoming viscuous at cone 5. Whether this is due to a high magnesia content remains to be seen.

Although highly calcareous clays are looked on with disfavor by some, for the manufacture of brick, it is certain that a large number of the Wisconsin clays produce a product of excellent strength.

Magnesia. Considering the run of clays from all states it can be said that magnesia is rarely present in quantities exceeding one per cent. In the Wisconsin ones however it has been found to run as high as 12.25 per cent. Although several minerals may serve as sources of it, the common one in the Wisconsin clays is probably the mineral dolomite, a double carbonate of lime and magnesia.

Magnesia has been usually regarded as having an effect on clay similar to lime, but experiments by Mäckler* have indicated that it is a less powerful flux, and separates the points of incipient fusion and vitrification more than lime does.

Alkalies. Under this head are included potash and soda. Most clays contain but a small percentage of them, but some, such as one described from Platteville, contain a large quantity, viz., over 9 per cent.

Feldspar and the white mica, muscovite, are the most common source of alkalies in clays, although other minerals such as hornblende or garnet might supply them, but they are rarely present in clay in any quantity.

Alkalies are considered to be the most powerful fluxing material that the clay contains, and if present in the form of silicates are a desirable constituent except in fire clays. Mica if very finely divided may flux with other ingredients of the clay at as low a temperature as cone 4, but if coarse grained the scales retain their identity even up to cone 9 or 10. Feldspar fuses at cone 9 but may flux some at a lower cone.

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*Thonindustrie Zeitung, vol. XXVI, p. 706.

Titanium. This element is absent from few clays, and most of the analyses made for this report show small amounts of it. Whether it enters into fluxing action with the other grains at low temperatures is not known, but in fire clays it is to be reckoned as a flux. It will if present in amounts of perhaps 5 or 6 per cent yield a yellow coloration at high cones. It seems not improbable too that it causes the yellowish tints in some kaolins, which show an exceedingly low percentage of iron oxide.

Water. Two kinds of water are recognized, viz. 1. Mechanically combined water or moisture and 2. chemically combined water.

Moisture is the water held in the pores of the clay chiefly by capillarity, and fills the spaces between the clay grains. When these are all small, the clay may absorb and retain a large quantity, because each interspace acts like a capillary tube. If the spaces exceed a certain size, they will no longer hold the moisture by capillary action, and the water, if poured on the clay, drains off. The fine-grained clays and sands, for these reasons, show higher powers of absorption and retention, while while coarse sandy clays or sands represent a condition of minimum absorption. This same phenomonon shows itself in the amount of water required for tempering a clay. Thus a very coarse sandy clay from Milladore required but 18.7 per cent of water for mixing, while a very plastic one from Eau Claire required 39.6 per cent. Highly aluminous clays do not necessarily absorb a high amount of water.

Moisture passes off partly by evaporation in air, but the last traces are expelled only by heating the clay to 100° C. (212° F.). The evaporation is accompanied by a shrinkage of the mass, which ceases, however, before all the moisture has left the clay, but these last traces are not expelled until the bricks are placed in the kiln.

Rapid expulsion of moisture may result in a cracking of the brick. If the clay contains soluble salts, the water brings these to the surface and leaves them there as a scum.

Chemically combined water, is that which exists in chemical combination with other elements, and is driven off by heating the clay to a temperature ranging from 400° C. (752° F.) to

600° C. (1112° F.). The minerals which yield most of it are kaolinite, muscovite, or white mica, and limonite. Hydrous silica and gypsum if present would add to the supply, but the water contained in the latter passes off at 250° C. (482° F.). In most clays the larger part of the combined water appears to be supplied by some hydrous aluminum silicate, possibly kaolinite and is usually about one-third the amount of alumina in the clay. After the water has been driven off the clay is left in a somewhat porous condition.

Organic Matter or Carbon. Although this includes all fragments of vegetable origin, whether large or small, it is the finely divided carbonaceous matter in the clay, with which the clay worker has to reckon. Organic matter, of coaly character, even in small quantities usually colors a clay gray or black.

In clay working its effect is chiefly noticeable in burning the wares. Carbonaceous matter will burn out of clay at a red heat, provided it can have a supply of air. This it usually gets if the fire is oxidizing and the clay remains porous until the carbon is burned off. If, however, the clay is dense-burning and the firing proceeds too rapidly, the carbonaceous matter becomes imprisoned in the brick before it can burn out, and later when the heat is raised the organic matter is decomposed with the evolution of gases, which in their effort to escape, will, if present in sufficient quantity, bloat and blister the ware. This does not happen unless the clay contains more than one or two per cent of organic matter. Clays with two per cent of organic matter are difficult to burn unless very sandy or molded dry press.

In most clay analyses the organic matter is not determined separately, but included under loss on ignition.

Soluble salts. Probably all clays contain a small percentage of soluble material, although this rarely exceeds two or three-tenths per cent. During the drying of the clay the moisture brings these to the surface, and deposits them there as a scum. These soluble salts are commonly sulphates of the alkalies, magnesia and perhaps lime, and their presence often causes the manufacturers considerable trouble.

If a clay free from these cannot be used, it is customary to add either barium carbonate or barium chloride to the clay in tempering to either render them insoluble, or form such easily soluble compounds that they will readily wash off.

In some instances these soluble compounds remain in the burned brick, and do not come to the surface until the ware is set in the wall. Hard burning will sometimes fix such substances by fusion, but experiments showed that in some bricks at least they remained in a soluble form even when the brick was fired to cone 3. Thus four samples of a cream-burning clay, representing different degrees of firing, were taken from a kiln in eastern Wisconsin. Two hundred grams of each brick were ground up sufficiently fine to pass a 100 mesh sieve. Two gram samples were then taken from each and placed in distilled water, which was warmed for several hours with occasional stirring. The water was then filtered off and the clear filtrate evaporated to dryness, the percentages obtained being given below. A, representing the soft burned, and E the hard burned.

	Per cent.
A	4.50
B	2.20
C	1.42
D	1.23
E	1.03

This shows that the harder the firing the less the quantity of soluble matter in the brick. It is somewhat difficult to see why the percentage of soluble matter in the brick is so much higher than it is the raw clay, in which it is not over a few tenths per cent. It seems improbable that any should form in burning, as there is no pyrite in the clay, and the thought suggests itself that it may be due in part to the water used in tempering, or possibly due to sulphur trioxide in the fuel gases, attacking some of the compounds in the clay, with the formation of soluble sulphates.

PHYSICAL PROPERTIES OF CLAY.

The physical properties of clay are of more importance to the practical clayworker than the chemical composition, since they give data which can be readily and quickly grasped, and which bear directly on his work. They are, moreover, properties with which he has already gained familiarity, even though he may not have defined them in exact terms.

Those which are most prominent are plasticity, tensile strength or bonding power, shrinkage, fusibility, texture, color, slaking qualities, and absorption.

Plasticity, or the property which clay has of forming a plastic mass when wet, is a characteristic of all clays and shales, but possessed by different ones to a variable degree, so that they range from those of very low plasticity, or lean ones, which are very sandy, to others of high plasticity which are termed fat. With these few facts in mind it becomes apparent that the plasticity of any clay can be adjusted to some extent at least by artificial means. Clays which are too fat or plastic can have their plasticity reduced by the incorporation of sand or less plastic clays, while those which are too lean, can be rendered more plastic by mixing in fat clays, or removing the sand.

Since the air and fire shrinkage usually stand in close relation to the plasticity, the possibility of controlling the latter property is also of importance to the manufacturer.

At many yards a mixture of several beds is used, in order to reach the proper degree of pastiness. Highly plastic clays, exhibit a tendency toward high air and fire shrinkage, while lean clays show the contrary. The latter, however, are often deficient in their bonding qualities.

Sedimentary or stratified clays are commonly of higher plasticity than residual ones, but there are naturally exceptions under each group.

The degree of plasticity of any clay cannot be inferred from its chemical analysis.

Tensile strength or bonding power. The tensile strength of a clay is the resistance which it offers to rupture when air dried and is an important property by virtue of which the unburned clay ware is able to resist shocks and strains in handling and which property also enables the clay to carry a variable amount of non-plastic material such as sand, which is often added to improve it. It is sometimes possible to get a general idea of the probable tensile strength of a clay from the degree of plasticity or stickiness which it appears to have and yet there is no constant relation between the tensile strength of the clay and its plasticity. All we can say is that many plastic clays have a high tensile strength and that many lean clays have a low tensile strength. On the other hand some clays of lean character show a surprisingly high tensile strength, as for example, a very silty clay from Elkhorn, whose average tensile strength was 206 lbs. per sq. in. A high tensile strength does not necessarily indicate that the particles of the clay will cling together so firmly as to resist cracking during drying, for some clays with a high bonding power show a strong tendency to crack when dried fast. For example, one of the estuarine clays of southeastern Wisconsin has a tensile strength of 228 pounds per square inch, but if this same clay is rapidly dried it cracks badly.

The tensile strength is measured by molding the tempered clay into briquettes of the same form and dimensions as those made for testing cement, and when these are thoroughly air dried they are pulled apart in a suitable testing machine. The cross section of the briquettes when molded is one square inch. After being formed they are allowed to dry first in the air and then in a hot air bath at a temperature of 100° C. (212° F.). When thoroughly dried the briquette is tested. Theoretically the briquette should break at its smallest cross section with a smooth straight fracture, and when this does not occur it is due to a flaw in the briquette or because the clips tend to cut into the clay. In such event the briquette breaks across one end and to prevent this it is necessary to put some soft material such as asbestos facing or rubber between the clip points and the sides of the briquette. If the briquettes are molded and dried with care the variation in the breaking strength of the individual briquettes should not vary more than 15 or 20 per cent, but with some very plastic clays it is extremely difficult to keep the variation between these limits.*

In testing the Wisconsin samples the tensile strengths given are the average of twelve briquettes and in the cream burning series tested the tensile strengths ranged from an average of 64 pounds per square inch to 386 pounds per square inch. The residual clays range in their tensile strength from 96 pounds per square inch to 339 pounds per square inch.

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*The tensile strength of clay briquettes is expressed in pounds per square inch, but since the briquette shrinks in drying the strength actually obtained in testing will be less than that for a square inch, and the result must be increased in proportion to the amount the briquette has shrunk.

The tensile strength of the clay is probably due in part to an interlocking of the clay grains as well as the presence of colloidal matter which acts as a cement. Clays which are made up entirely of fine grains or coarse grains often show a low tensile strength and those which are made up of a mixture of sizes seem to produce a maximum strength.

The tensile strength of most clays is usually lowered by the addition of coarse sand, but a mixture of two clays may some times show a higher tensile strength than either of the clays alone.

Shrinkage. All clays shrink in drying and burning, the former loss being termed the air shrinkage and the latter the fire shrinkage.

Air shrinkage. The air shrinkage is the decrease in volume which a clay shows after being molded and is caused by the drawing together of the clay particles as the water evaporates from the molded mass. This continues until all particles have come into contact, but since even then there are some pores left in the clay there may still be some water left in the material after the air shrinkage has ceased. The amount of air shrinkage is usually low in lean clays and high in plastic ones for the reason that the former absorb but little water in mixing and the latter a large quantity of it. The clays however which absorb the higher amount of water in mixing do not necessarily show the higher air shrinkage. The air shrinkage of any one clay will also vary not only with the amount of water added but also with the amount of pressure given the material in molding so that soft-mud bricks often show a high air shrinkage and dry-press bricks none at all. The addition of sand to a clay will in nearly every case lower its air shrinkage and for this reason the air shrinkage of many soft-mud bricks is low because a considerable quantity of sand is incorporated with the clay during the tempering process. The effect of sand on the air shrinkage can be seen, by comparing the physical tests of the clay and brick mixtures given on the later pages.

While coarse and sandy clays shrink less than the fine grained ones they may absorb considerable water especially if they are silty in their character, but the fact that their pores are much coarser allows the water to escape rapidly and thus often permits more rapid drying. The cracking of some fine-grained clays in drying is due to the surface shrinking more rapidly than the interior because the evaporation there is greatest. As the outer portion of the product cannot stretch it must pull apart and crack.

Fire shrinkage. All clays shrink during some stage of the burning operation even though they sometimes expand slightly at certain temperatures (calcareous and many siliceous clays). The fire shrinkage, however, varies within wide limits; the amount depending partly on the quantity of volatile elements such as combined water, organic matter, and carbon dioxide present in the clay, and partly on the texture. It reaches a maximum when the clay vitrifies but it does not increase uniformly up to that point and in fact is very irregular. Thus a certain amount of shrinkage takes place when the combined water begins to pass off, namely at 400° C. (752° F.) and an additional amount occurs at higher temperatures, but the latter is frequently not the result of the contraction following the volatilization of some of the elements. Wherever the fire shrinkage is given in this report it refers to the linear shrinkage during the burning and is expressed in terms of the length of the bricklet when molded. Thus if the fire shrinkage at cone 1 is given as 4 per cent it means that the amount of fire shrinkage at that cone is 4 per cent of the length of the bricklet when freshly molded. Between the points at which chemically combined water passes off and 1000° C. there is practically no fire shrinkage but above this point the contraction begins again. As an illustration of the way in which the fire shrinkages vary in the different clays we may take the following examples:

No. 1. Plastic clay from Maquoketa shale.
No. 2. Gritty, residual clay from Stevens Point.
No. 3. Calcareous clay from Watertown.
No. 4. Residual clay from Eau Claire.

Cone.	010	05	03	1	3
I..........	.6	1.7	4	Viscous...	....
II..........	1	1.3	3	4.9	....
III..........	0	Slightly swelled..	Slightly swelled..	Slightly swelled..	2
IV..........	1	4.7	6.3	8	8.3

Since many clays when burned shrink to such an extent as to cause loss from warping and cracking it is necessary to add materials which of themselves have no fire shrinkage thus decreasing the shrinkage of the mixture in burning. Sand or sandy clays are the materials most commonly used for this purpose but ground bricks (grog), and even coke or graphite may be employed. In Wisconsin sand and ground bricks are the only materials used.

The various anti-shrinkage agents serve not only to decrease the shrinkage in drying and burning but also tend to prevent blistering in an easily fusible ferruginous clay when hard fired. They also serve to increase the porosity of the ware and thus facilitate the escape of the moisture in drying and in the early stages of burning as well as often enabling the products to withstand sudden changes of temperature. If sand is added for this purpose it may act as a flux at higher temperatures and this action will be the more intense the finer its grain. Large particles of grog are undesirable especially if they are angular in form because in burning the clay shrinks around them and the sharp edges serve as a wedge opening cracks in the clay which may expand to an injurious degree. Large pebbles and lumps of tough clay which have not been broken up in tempering will do the same.

Fusibility. The changes which occur in the early stages of burning have already been referred to. With the increase in temperature above 1000° C. a softening of the clay grains begins; and as a result of this softening which represents the stage of incipient infusion, hardening of the mass takes place. While at this stage the clay may have softened sufficiently to weld together, the fusion has not been intense enough to prevent the identification of the coarser grains in the clay. With a further increase in temperature, the amount depending on the character of the clay, an additional amount of shrinkage occurs and many of the particles become sufficiently soft to allow the mass to settle or compact itself into an impervious condition thus closing up all the pores in the clay. This is termed the condition of vitrification and the piece of vitrified clay when broken shows a very smooth fracture and sometimes a slight lustre since all the particles except the coarse quartz grains have been melted together into a dense solid mass.

Vitrification, since it represents a condition of close compactness of the clay particles is also the point of maximum shrinkage. If the heat is raised still further the clay softens so that it can no longer hold its shape and flows or gets viscous. The custom has therefore been to speak of three stages* in the burning of the clay, namely incipient fusion, vitrification, and viscosity. It is however usually difficult to recognize exactly the exact point of attainment of these three conditions for the clay may soften so slowly that the change from one to the other is very gradual. The difference in temperature between the points of incipient fusion and viscosity varies with the composition of the clay. In many calcareous clays these points are within 27.7° C. (50° F.) of each other, while in refractory ones they may be 377.7°C. (700°F.) to 444.4°C. (800°F.) apart. The practical importance of having a clay in which the points of incipient fusion and viscosity are well separated is usually clearly recognized in the manufacture of many clay products where the aim is to produce a vitrified or impervious ware. If the temperature interval between the points of vitrification and viscosity is small it is difficult to bring the ware up to a condition of vitrification without the risk of reaching the temperature of viscosity and melting the contents of the kiln, because it is impossible to control the kiln temperature within a range of a few degrees. The point of vitrification is not always midway between that of incipient fusion and viscosity.

The temperature of fusion of the clay depends on (1) the amount of fluxing impurities, (2) the condition of these fluxes, (3) the size of the grains and (4) the condition of the kiln atmosphere, whether oxydizing or reducing.

1. Other things being equal the temperature of fusion of a clay falls as the percentage of total fluxes rises. Thus a brick clay shows a much lower fusion point than a fire clay because it has a much higher percentage of fluxes. It should be pointed out in this connection however that all fluxes and impurities do not act with equal energy, some being more active than others.

2. The condition of the fluxes may also affect the result. Thus lime, for example (if present in the form of carbonate of

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*H. A. Wheeler. Vitrified Paving Brick, p. 12, 1895. Ind.

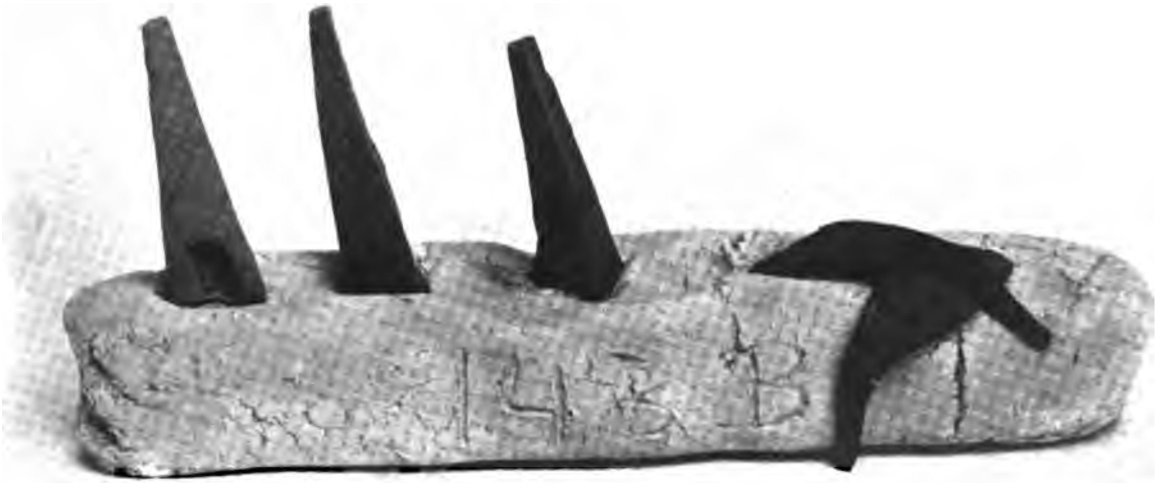
lime will induce a fluxing action in the clay at a lower temperature than will be the case if the lime is present as a silicate.

3. The size of the mineral grains in the clay also affects the fusing point. Other things being equal a fine-grained clay will fuse at a lower temperature than a coarse grained one for the reason that when the particles of a clay begin to fuse or flux with each other this action begins on the surface of the grains and works inwards towards the center. If therefore the easily fusible grains are of small size they fuse more rapidly and are more effective in their fluxing action than if the grains were large. Since some of the mineral grains in the clay are more refractory than others the clay in its earlier stages of fusion can be regarded as a mixture of fused particles with a skeleton of unfused ones. If the proportion of the former to the latter is large there will be a strong hardening of the clay with little shrinkage and the burned clay will still be porous. With an increase of the temperature and the fusion of more particles the pores fill up more and more and the shrinkage goes on until at the point of vitrification the spaces are practically all filled. Above this point there is no longer a sufficiently strong skeleton to hold the mass together and the clay begins to flow. The conditions which influence the difference in temperature between vitrification and viscosity still remain to be satisfactorily explained but it probably depends on the relative amount of fluxes and non-fluxes and the size of grain of each.

4. Finally it is found that the same clay will fuse at a lower temperature if in burning it is deprived of oxygen than it will if burned in an atmosphere containing plenty of the latter.

Determination of fusibility. The temperature at which a clay fuses is determined either by means of test pieces of known composition, or by some form of apparatus or mechanical pyrometer, the principle of which depends on the expansion of gases or solids, thermoelectricity, spectrophotometry, etc.

Seger cones. These test pieces consist of a series of mixtures of clay with fluxes, so graded that they represent a series of fusion points, each being but a few degrees higher than the one next to it. They are so called because originally introduced by H. Seger, a German ceramist. The materials which he used in making them were such as would have a constant composition, and consisted of washed Zettlitz kaolin, Röstrand



Seger cones after heating in kiln.

feldspar, Norwegian quartz, Carrara marble, and pure ferric oxide. Cone No. 1 melts at the same temperature as an alloy composed of one part of platinum and nine parts of gold, or at 1150°C. (2102°F.). Cone No. 20 melts at the highest temperature obtained in a porcelain furnace, or at 1530° C. (2786° F.). The difference between any two successive numbers is 20° C. (36°F.), and the upper member of the series is cone 36, which is composed of a very refractory clay slate, while cone 35 is composed of kaolin from Zettlitz. Cramer of Berlin, made a series below No. 1 by mixing boracic acid with the materials already mentioned. Hecht obtained still more fusible mixtures by adding both boracic acid and lead in proper proportions to the cones. The result is that there is now a series of 58 numbers, the fusion point of the lowest being 590° C. (1094° F.), and that of the highest 1850°C. (3362°F.).

For practical purposes these cones are very successful, though their use has been somewhat unreasonably discouraged by some. They have been much used by foreign manufacturers of clay products and their use in the United States is increasing. The full series can be obtained from Messrs. Seger and Cramer of Berlin, for $0.01 each (or about two and one-half cents apiece, including duty and expressage), or numbers .010 to 35 can be obtained for $0.01 each from Prof. E. Orton, Jr., of Ohio State University, Columbus O.

The table of fusing points of these cones and their composition is given below:

Composition and fusing points of Seger cones.

No. of cone.	Composition.			Fusing Point.	
				°F.	°C.
.022	0.5 Na_2O 0.5 PbO	....	2.0 SiO_2 1.0 B_2O_3	1,094	590
.021	0.5 Na_2O 0.5 PbO	0.1 Al_2O_3	2.2 SiO_2 1.0 B_2O_3	1,148	620
.020	0.5 Na_2O 0.5 PbO	0.2 Al_2O_3	2.4 SiO_2 1.0 B_2O_3	1,202	650
.019	0.5 Na_2O 0.5 PbO	0.3 Al_2O_3	2.6 SiO_2 1.0 B_2O_3	1,256	680
.018	0.5 Na_2O 0.5 PbO	0.4 Al_2O_3	2.8 SiO_2 1.0 B_2O_3	1,310	710
.017	0.5 Na_2O 0.5 PbO	0.5 Al_2O_3	3.0 SiO_2 1.0 B_2O_3	1,364	740
.016	0.5 Na_2O 0.5 PbO	0.55 Al_2O_3	3.1 SiO_2 1.0 B_2O_3	1,418	770
.115	0.5 Na_2O 0.5 PbO	0.6 Al_2O_3	3.2 SiO_2 1.0 B_2O_3	1,472	800
.014	0.5 Na_2O 0.5 PbO	0.65 Al_2O_3	3.3 SiO_2 1.0 B_2O_3	1,526	830
.013	0.5 Na_2O 0.5 PbO	0.7 Al_2O_3	3.4 SiO_2 1.0 B_2O_3	1,580	860
.012	0.5 Na_2O 0.5 PbO	0.75 Al_2O_3	3.5 SiO_2 1.0 B_2O_3	1,634	890
.011	0.5 Na_2O 0.5 PbO	0.8 Al_2O_3	3.6 SiO_2 1.0 B_2O_3	1,688	920
.010	0.3 Na_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.50 SiO_2 0.50 B_2O_3	1,742	950

Composition and fusing points of Seger cones—Continued.

No. of cone.	Composition.			Fusing Point.	
				°F.	°C.
.09	$0.3\,K_2O$ $0.7\,CaO$	$0.2\,Fe_2O_3$ $0.3\,Al_2O_3$	$3.55\,SiO_2$ $0.45\,B_2O_3$	1,778	970
.08	$0.3\,K_2O$ $0.7\,CaO$	$0.2\,Fe_2O_3$ $0.3\,Al_2O_3$	$3.60\,SiO_2$ $0.40\,B_2O_3$	1,814	990
.07	$0.3\,K_2O$ $0.7\,CaO$	$0.2\,Fe_2O_3$ $0.3\,Al_2O_3$	$3.65\,SiO_2$ $0.35\,B_2O_3$	1,850	1,010
.06	$0.3\,K_2O$ $0.7\,CaO$	$0.2\,Fe_2O_3$ $0.3\,Al_2O_3$	$3.70\,SiO_2$ $0.30\,B_2O_3$	1,886	1,030
.05	$0.3\,K_2O$ $0.7\,CaO$	$0.2\,Fe_2O_3$ $0.3\,Al_2O_3$	$3.75\,SiO_2$ $0.25\,B_2O_3$	1,922	1,050
.04	$0.3\,K_2O$ $0.7\,CaO$	$0.2\,Fe_2O_3$ $0.3\,Al_2O_3$	$3.80\,SiO_2$ $0.20\,B_2O_3$	1,958	1,070
.03	$0.3\,K_2O$ $0.7\,CaO$	$0.2\,Fe_2O_3$ $0.3\,Al_2O_3$	$3.85\,SiO_2$ $0.15\,B_2O_3$	1,994	1,090
.02	$0.3\,K_2O$ $0.7\,CaO$	$0.2\,Fe_2O_3$ $0.3\,Al_2O_3$	$3.90\,SiO_2$ $0.10\,B_2O_3$	2,030	1,110
.01	$0.3\,K_2O$ $0.7\,CaO$	$0.2\,Fe_2O_3$ $0.3\,Al_2O_3$	$3.95\,SiO_2$ $0.05\,B_2O_3$	2,066	1,130
1	$0.3\,K_2O$ $0.7\,CaO$	$0.2\,Fe_2O_3$ $0.3\,Al_2O_3$	$4\,SiO_2$	2,102	1,150
2	$0.3\,K_2O$ $0.7\,CaO$	$0.2\,Fe_2O_3$ $0.4\,Al_2O_3$	$4\,SiO_2$	2,138	1,170
3	$0.3\,K_2O$ $0.7\,CaO$	$0.05\,Fe_2O_3$ $0.45\,Al_2O_3$	$4\,SiO_2$	2,174	1,190
4	$0.3\,K_2O$ $0.7\,CaO$	$0.5\,Al_2O_3\,4\,SiO_2$		2,210	1,210

Composition and fusing point of Seger cones—Continued.

No. of cones.	Composition.	Fusing Point.	
		°F.	°C.
5	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}0.5\ Al_2O_3 5\ SiO_2$..........	2,246	1,230
6	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}0.6\ Al_2O_3 6\ SiO_2$..........	2,282	1,250
7	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}0.7\ Al_2O_3 7\ SiO_2$..........	2,318	1,270
8	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}0.8\ Al_2O_3 8\ SiO_2$..........	2,354	1,290
9	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}0.9\ Al_2O_3 9\ SiO_2$..........	2,390	1,310
10	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}1.0\ Al_2O_3 10\ SiO_2$.........	2,426	1,330
11	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}1.2\ Al_2O_3 12\ SiO_2$.........	2,462	1,350
12	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}1.4\ Al_2O_3 14\ SiO_2$.........	2,498	1,370
13	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}1.6\ Al_2O_3 16\ SiO_2$.........	2,534	1,390
14	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}1.8\ Al_2O_3 18\ SiO_2$.........	2,570	1,410
15	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}2.1\ Al_2O_3 21\ SiO_2$.........	2,606	1,430
16	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}2.4\ Al_2O_3 24\ SiO_2$.........	2,642	1,450
17	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}2.7\ Al_2O_3 27\ SiO_2$.........	2,678	1,470

Composition and fusing point of Seger cones—Continued.

No. of cone.	Composition.	Fusing Point.	
		°F.	°C.
18	$\begin{Bmatrix}0.3\,K_2O\\0.7\,CaO\end{Bmatrix}$ 3.1 Al_2O_3 31 SiO_2	2,714	1,490
19	$\begin{Bmatrix}0.3\,K_2O\\0.7\,CaO\end{Bmatrix}$ 3.5 Al_2O_3 35 SiO_2	2,750	1,510
20	$\begin{Bmatrix}0.3\,K_2O\\0.7\,CaO\end{Bmatrix}$ 3.9 Al_2O_3 39 SiO_2	2,786	1,530
21	$\begin{Bmatrix}0.3\,K_2O\\0.7\,CaO\end{Bmatrix}$ 4.4 Al_2O_3 44 SiO_2	2,822	1,550
22	$\begin{Bmatrix}0.3\,K_2O\\0.7\,CaO\end{Bmatrix}$ 4.9 Al_2O_3 49 SiO_2	2,858	1,570
23	$\begin{Bmatrix}0.3\,K_2O\\0.7\,CaO\end{Bmatrix}$ 5.4 Al_2O_3 54 SiO_2	2,894	1,590
24	$\begin{Bmatrix}0.3\,K_2O\\0.7\,CaO\end{Bmatrix}$ 6.0 Al_2O_3 60 SiO_2	2,930	1,610
25	$\begin{Bmatrix}0.3\,K_2O\\0.7\,CaO\end{Bmatrix}$ 6.6 Al_2O_3 66 SiO_2	2,966	1,630
26	$\begin{Bmatrix}0.3\,K_2O\\0.7\,CaO\end{Bmatrix}$ 7.2 Al_2O_3 72 SiO_2	3,002	1,650
27	$\begin{Bmatrix}0.3\,K_2O\\0.7\,CaO\end{Bmatrix}$ 20 Al_2O_3 200 SiO_2	3,038	1,670
28	Al_2O_3 10 SiO_2	3,074	1,690
29	Al_2O_3 8 SiO_2	3,110	1,710
30	Al_2O_3 6 SiO_2	3,146	1,730
31	Al_2O_3 5 SiO_2	3,182	1,750
32	Al_2O_3 4 SiO_2	3,218	1,770
33	Al_2O_3 3 SiO_2	3,254	1,790
34	Al_2O_3 2.5 SiO_2	3,290	1,810
35	Al_2O_3 2 SiO_2	3,326	1,830
36	Al_2O_3 1.5 SiO_2	3,362	1,850

If the heat is raised too rapidly the cones which contain much iron swell and blister and do not bend over, so that the best results are obtained by the slow softening of the cone under a gradually rising temperature. In actual use they are placed in the kiln at a point where they can be watched through a peep hole, but at the same time will not receive the direct touch of the flame from the fuel. It is always well to put two or more cones of different numbers in the kiln, so that warning can be had, not only of the end point of firing, but also of the rapidity with which the temperature is rising.

In determining the proper cone to use in burning any kind of ware, several cones are put in the kiln, as for example, numbers .08, 1 and 5. If .08 and 1 are bent over and 5 is not affected, the temperature of the kiln is between 1 and 5. The next time numbers 2, 3 and 4 are put in, and 2 and 3 may be fused, but 4 remains unaffected, indicating that the temperature reached the fusing point of 3.

The cone numbers used in the different branches of the clay working industry in the United States are approximately as follows:

Common brick	010—01
Hard-burned, common brick	1— 2
Buff-front brick	6— 8
Hollow blocks and fireproofing	03— 1
Terra cotta	04— 7
Conduits	7— 8
White earthenware	8— 9
Fire bricks	9—12
Porcelain	11—13
Red earthenware	010—05
Stoneware	6— 8

While the temperature of fusion of each cone is given in the preceding table, it must not be understood that these cones are for measuring degrees of temperature, but rather for measuring pyrochemical effects. Thus if certain changes are produced in a clay at the fusing point of cone 5, the same changes can be reproduced at the fusion point of this cone, although the actual temperature of fusion may vary somewhat, due to variations in the condition of the kiln atmosphere. As a matter of fact, however, repeated tests with a thermoelectric pyrometer demonstrates that the cones commonly fuse close to the theoretic temperatures.

Manufacturers occasionally claim that the cones are unreliable and not satisfactory, forgetting that their misuse may often be the true reason for irregularities in their behavior. It is unnecessary, perhaps, to state that certain reasonable precautions should be taken in using these test pieces. The cones are commonly fastened to a brick with a piece of wet clay, and should be set in a vertical position. After being placed in a position where they can be easily seen through a peep hole, the latter should not be opened widely during the burning lest a cold draft strike the cone, and a skin form on its surface and interfere with its bending. Moreover, one set of cones cannot regulate an entire kiln, but several sets should be placed in different portions of the same. One advantage possessed by a cone over trial pieces is that the cone can be watched through a small peep hole, while a larger opening must be made to draw out the trial piece.

Thermoelectric pyrometer. This pyrometer, which is the only one that will be described in this report, is one of the best instruments for measuring temperatures. It is based on the principle of generating an electric current by the heating of a thermopile or thermoelectric couple. This consists of two wires, one of platinum and the other of an alloy of 90 per cent platinum and 10 per cent rhodium. These two are fastened together at one end, while the two free ends are carried to a galvanometer which measures the intensity of the current. That portion of the wires which is inserted into the furnace or kiln is placed within two fire-clay tubes, one of the latter being smaller and sliding within the other in order to insulate the wires from each other. The larger tube has a closed end to protect the wires from the action of the fire gases.

To measure the temperature of a furnace or kiln the tube containing the wires is placed in it either before starting the fire, or else during the burning. If the latter method is adopted, the tube must be introduced very slowly to prevent its being cracked by sudden heating. The degrees of temperature are measured by the amount of deflection of the needle of the galvanometer.

Thermoelectric pyrometers are useful for measuring the rate at which the temperature of a kiln is rising, or for detecting fluctuations in the same. It is not necessary to place the galvanometer near the kiln, for it can be kept in the office some rods away. This pyrometer is not to be used as a substitute for Seger cones but to supplement them. The more modern forms have an automatic recording device. As at present put on the market, the thermoelectric pyrometer costs about $180, and the price, delicacy of the instrument, and lack of realization of its importance have all tended to restrict its use. However, many of the larger clay-working plants are adopting it, as it is better than other forms of pyrometer for general use and probably more accurate. It can be used up to 1600° C. (2912° F.).

Cone tests in Wisconsin kilns. During the course of the work on the Wisconsin clays a number of cones were distributed among the brick and tile manufacturers who in most cases willingly placed them in their kilns, and after burning returned them to the office of the geological survey.

The cones were usually fastened to a strip of wet clay (Pl. III) of the same mixture as that used for bricks, and these placed in the kiln, surrounded by bricks so as to protect them as much as possible from flashing.

The cone temperatures of a number of kilns are given below:

Locality.		Cone.
Antigo		010
Athens		Barely 010
*Burlington		04
Clintonville (top of kiln)		Under 010
Clintonville (bottom of kiln)		010
Grand Rapids		010
Green Bay (red burning)		08
*Green Bay (cream burning)		1
*Kenosha		1
*Manitowoc (top of kiln)		08
*Manitowoc (bottom of kiln)		05
Marshfield		010
Menomonie	Different yards.	09
Menomonie		Barely 010
Merrill		010
*Merrimac		3
*Milwaukee		3
Monroe		Barely 010
*New London		010
Platteville		Under 010
*Portage		3
*Port Washington (top of kiln)		08
*Port Washington (bottom of kiln)		05
*Racine, North Point		2
Ringle		Under 010
*Schleisingerville		3

*Shawano	1
*Sheboygan	3
Siegel Station	010
Stevens Point	010
*Whitewater	1

Those marked with an * are creamburning calcareous clays, and it is interesting to note the higher cone, at which with few exceptions they are burned.

Texture. This term refers to the size of grain of the clay. While many clays contain sand grains sufficiently large to be easily seen with the naked eye the majority of the mineral particles in a clay are too small to be seen without the aid of the microscope and are in fact so small that they cannot be separated by means of sieves. In testing the texture of a clay it is perhaps of sufficient importance for practical work to determine the percentage of any sample that will pass through a sieve of 100 or 150 meshes to the inch, since in the preparation of clays for the market by the washing process they are not required to pass through a screen any finer than the one above mentioned.

Color. The color of unburned clay is commonly due either to carbonaceous matter or some iron compounds and a clay free from either of these is usually white. The carbonaceous matter most often imparts a gray or black color to the clay, although it has been claimed by some that it may even color the clay red or brown. A very small percentage is commonly sufficient to affect the color of the clay and 3 or 4 per cent will make it deep black, sandy clays being more intensely colored by a much smaller quantity than those free from sand.

Iron oxide colors a clay yellow, brown or red depending on the form of oxide present. The color of a green or raw clay is not always an indication of the color it will be when burned. Red clays usually burn red; deep yellow clays may burn buff; chocolate clays commonly burn red or reddish brown; white clays burn white; and gray or black clays may burn red, buff, or white. Calcareous clays when raw are often either red, yellow, gray, brown, or grayish, and may burn red at first and turn yellow or buff as fusion progresses, passing into a greenish yellow at viscosity.

Slacking. This refers to the property which a clay shows of falling to pieces when thrown into water and the rapidity with which the clay disintegrates varies in different clays. Most open, porous, sandy clays break down rapidly to a powdery mass; others may spawl or chip off slowly when immersed, while still others do not slack at all or only after long soaking. The slacking property is one of some practical importance as easily slacking clays temper more rapidly while if the material is to be washed it disintegrates more rapidly in the log washer. Some of the calcareous clays used in the state disintegrate very slowly in water and unbroken lumps of them are sometimes seen in the burned brick.

KINDS OF CLAY. Clays are used for many different kinds of product, and while one kind of clay is frequently adapted to the manufacture of several kinds of ware, the several groups into which clay products are divisible, commonly call for clays of widely different character.

There are frequently serious misconceptions among laymen, and even some clay workers regarding the requirements of a clay to be used for one or another purpose, and it may be well to give the essential characteristics of the more important types of clay.

Common-brick clays. Common brick are made from almost any kind of clay, and those available in Wisconsin range from the calcareous lake and estuarine clays, to the ferruginous residual clays found in the central part of the state. Too sandy clays should be avoided, and the loessoid clays used at La Crosse, Arcadia, Viola, and other localities in western Wisconsin are about as siliceous as is desirable.

Drain-tile clays. Drain tile are commonly made from the more plastic and finer-grained brick clays.

Pressed-brick clays. While many pressed brick are now made from semi-fire clays, in some regions much less refractory materials are employed. The prominent and essential characteristics are uniformity of shade and freedom from discoloration when burned, absence of warping, low shrinkage, and the production of a good hard body in firing.

Wisconsin contains an abundance of clays suitable for making pressed brick. The cream-burning clays are ultilized for dry-press brick at Milwaukee and Green Bay, but the same type of material could be employed at other localities. Red-burning clays are being worked for this purpose at Menomonee, but could also be found in other parts of the state.

Paving-brick clays. Paving brick are generally manufactured from non-refractory clays or shales of fine grain, ferruginous composition, good plasticity, and good tensile strength. They vitrify usually at a low temperature, cone 2–4, have a low fire shrinkage and burn to a dense red body. At some localities a mixture of low-grade fire clay and shale is sometimes preferred. The following analyses give the average composition of a number of carefully selected clays used for paving brick:

Analyses of clays used for making paving bricks.[*]

	Minimum.	Maximum.	Average.
Silica (SiO_2)	49.	75.	56.
Alumina (Al_2O_3)	11.	25.	22.50
Ferric oxide (Fe_2O_3)	2.	9.	6.70
Lime (CaO)	.20	3.50	1.20
Magnesia (MgO)	.10	3.00	1.40
Alkalies (Na_2O, K_2O)	1.00	5.50	3.70
Ignition	3.00	13 00	7.00

[*] Wheeler, Vitrified Paving Brick.

The analyses show that the iron oxide, lime, magnesia, and alkalies are usually rather high. It is not safe however to use the chemical analysis as a means of judging the value of a clay for paving brick manufacture.

Several of the clays from the residual area of Wisconsin fall within the limits here given and there is hope that they may be used for the manufacture of paving brick. I refer to those near Merrillan, Halcyon, and Pittsville. (See chapter on Residual Clays.)

Hollow-ware clays. Hollow bricks and fire proofing are often made from a red-burning clay, of low refractoriness and one which burns hard at a low cone. Since they are commonly molded by the stiff-mud process, they should be plastic, free from grit and stones. A low air and fire shrinkage is also desirable.

The mellowed or weathered Maquoketa shale from Grant and Lafayette counties, suggests itself as a material which is perhaps excellently adapted to this line of work. Some of the calcareous clays have also been tried for hollow-brick, but are less desirable than the red ones.

Earthenware clays. Common earthenware is made from impure clays, of good plasticity, and fine grain, which burn moderately hard at a low cone, about 010. They must turn readily on a potter's wheel, and burn to a porous body without excessive shrinkage. Most smooth plastic clays, whether cream or red-burning, can be employed for making common earthenware, and can be found in many parts of the state, but are little utilized.

Terra-cotta clays. Most terra-cotta manufacturers employ a mixture of low grade fire clays for making terra-cotta. Its manufacture calls for a material, or mixture of materials which will burn to a good hard body, sufficient density, have low to moderate shrinkage, and not warp or crack in firing. With the clay there is usually mixed a variable amount of grog. None of the clays thus far discovered in Wisconsin are likely to be of use for this purpose.

Stoneware clay. Stoneware is usually made of a semi-refractory clay, which burns to a vitrified body at from cone 6 to 8, and holds its form well in burning. A No. 2 fire clay is found to sometimes answer the requirements. Stoneware is rarely made from one clay alone, but usually from a mixture of clays. None of the Wisconsin clays observed would serve for this purpose and it seems doubtful if any stoneware clays will be found in the state.

Fire clays are clays of good refractoriness, that is to say, their fusion point should be at least equal to that of cone 27 and preferably higher. They contain a low percentage of total fluxes, commonly not more than 5 or 6 per cent, and burn to a light buff, but in all other properties they show considerable variation. None are mined in Wisconsin at the present time, and the only region in which they are likely to be found is around Hersey or Glenwood. The deposits formerly worked there have been abandoned. The shrinkage and density in burning often lead to their use for special purposes.

The commonest use is for fire brick, but they are also employed in the manufacture of glass pots, and as ingredients of terra-cotta, stoneware, and encaustic-tile bodies. It should be borne in mind that all limy clays which have not the remotest claim to refractoriness also burn buff.

Ball clays are white-burning clays of higher plasticity than china clays. They are used for much the same products as the latter, excepting paper, and are much more plastic than kaolins. The Hersey clays can perhaps be considered as intermediate between a ball clay and kaolin.

China clays. Clays included under this head, must be of the highest grade. In chemical composition they approach closely to kaolinite as shown by the analysis on p. 13, and have but a small percentage of fusible impurities. They should contain under 1 per cent ferric oxide, burn to a white color at cone 9, show high refractoriness and at least fair plasticity. They are never used alone, but always with an admixture of flint, feldspar, and ball clay. No such clays are now being mined in Wisconsin, nor did the writer see any deposits of this type. Those formerly dug at Hersey, were of sufficiently high grade to serve for white granite-ware manufacture. China clays are washed for market. They are used in the manufacture of porcelain, white earthenware, wall tile, floor tile, and paper.

Slip clays. This term is applied to those clays which are easily fusible, and melt to a glass or enamel at temperatures reached in burning terra cotta and stoneware. They show a high percentage of fluxing impurities and often show a large amount of alkalies. The occurrence of this type of clays is discussed in a separate chapter of the present report.

Paper clays. These form a type of clay much used by paper manufacturers and having special qualities. Since the clays are not to be molded or burned, behavior under fire is of no importance. The great essentials are whiteness of color and freedom from grit. The latter is often eliminated by washing. The clays formerly worked near Hersey were much used for paper manufacture.

CHAPTER II.

METHODS OF BRICK MANUFACTURE EMPLOYED IN WISCONSIN.

Although brick are now being manufactured at a number of localities, the equipment of most of the plants is quite simple, and the methods sometimes employed capable of improvement. This latter point is one of considerable importance for the future development of the Wisconsin brick industry, as in order to compete successfully with bricks shipped in from other states, the yards of this state must have large capacity, good shipping facilities, and clay which is easy to mold, dry, and burn.

Mining the clay. At the majority of the yards the clay bank or clay pit is comparatively small, and the mining is done with pick and shovel, the clay being hauled to the yards in carts. At some plants a light track is laid to the working face, and the cars loaded there are hauled by horse power down to the yard (Pl. V Fig. 2). This is an excellent plan to follow when the output of the yard is small. Where the clay deposit underlies a hill which slopes down to the yard, and there is little or no stripping, a good plan, and one adopted at some yards is to loosen the clay with plows and then collect it with scrapers. These latter bring it down to a platform through which or from which it is discharged onto cars or carts (Pl. IV Fig. 4), and hauled to the works. This method commends itself in those cases where the deposit is worked from a flat or sloping surface.

Steam shovels are employed for digging clay at some of the Milwaukee yards, (Pl. IV Fig 1). This is one of the best methods of mining where the quantity of clay required is large, the

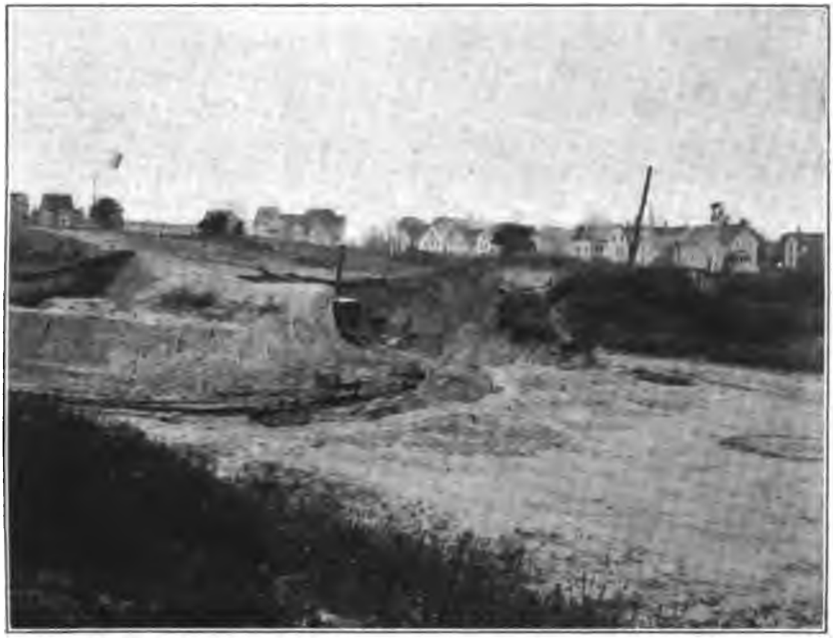


Fig. 1. Clay pit of Standard Brick Co., Clement Ave., Milwaukee. The steam shovel is used to dig the clay. The large mass which partly hides the shovel is sandy clay of no value.

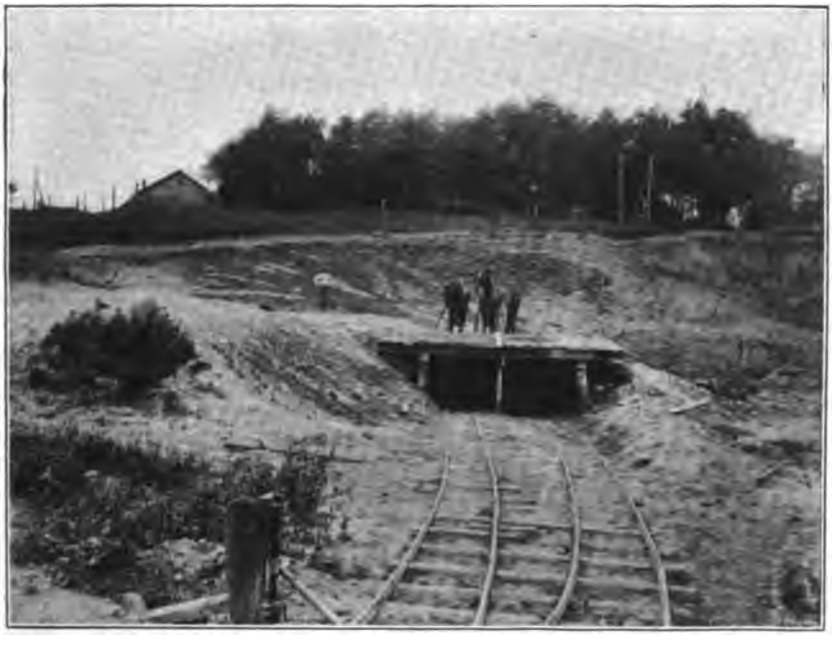


Fig. 2. Clay bank at Davelaar's yard, Milwaukee. Showing the method of working the clay with plows and scrapers dumping it on the platform.

bank not too high, and the run of the deposit to be used. There are at present however few localities outside of Milwaukee where the scale of operations warrants the use of shovels. Moreover steam shovels could not be economically used in many of the deposits where both red and cream-burning clays occur in the same section of no great thickness, unless it is desired to mix the two together.

Their use in the residual area should also be considered with caution, unless the homogeneity and depth of the deposit, as well as freedom from rocky masses is assured.

It would therefore appear that at most localities the mining of the clay with pick and shovels, or with plows and scrapers, (according to the conditions) is the best method to employ.

The mixture. Very few yards made their bricks from one layer alone, but instead mix it with sand, or take the run of the bank, which includes the top layer of sand or loam commonly present. The incorporation of sand is desirable partly because it decreases the air shrinkage in drying, and because in burning its addition renders the calcareous clays more dense, and in some cases lessens the fire shrinkage. If the top sand is gravelly or stony the precaution should be taken to see that it is thoroughly screened. Neglect of this often causes serious injury to the brick, the more so if the pebbles are calcareous.

Tempering. For making soft-mud or stiff-mud bricks, the raw material is prepared in soak pits, ring pits, or pug mills. Of the three types the pug mill is most commonly employed, the clay being sometimes passed first through a pair of rolls. Rolls alone are of little advantage. Right here is where the utmost care is necessary, for many of the lake and estuarine clays are tough and slake slowly, and if not thoroughly tempered, there will be lumps of uncrushed clay left in the brick which cause cracking in drying and burning, and also lower the transverse strength of the brick. Soak pits and ring pits are of small capacity as compared with pug mills, and to be avoided if a large output from a few machines is desired.

Molding methods. All three methods of molding are employed in Wisconsin, viz., the soft-mud, stiff-mud, and dry-press. The first named is used most, and the last named least. There does not seem to have been any definite reason in many cases for the choice of machinery made at some yards, except cost. Considering the characters of the clays, it will be seen however that certain types work best with certain kinds of machine. Thus the sandy clays of the loess area in western Wisconsin, and many of the sandy surface clays of glacial origin, are best adapted to the soft-mud process, as owing to their grittiness and rather low plasticity they would not be likely to work well in a stiff-mud machine unless mixed with a more plastic clay.

The stiff-mud process on the other hand gives excellent results with the cream-burning estuarine and lake clays, although the soft-mud process likewise works well.

In the residual area the soft-mud process, and stiff-mud process of molding are both used. When both brick and drain tile are made at the same yard, the stiff-mud machine has the advantage in that both types of product can be molded in it. So far as the writer is aware no repressing whatever is done on any of the Wisconsin brick.

The dry-press process is used at but three or four localities in the state but there is no apparent reason why its use should not be extended. It is now used for the lake clays at Milwaukee, Port Washington, and Green Bay, the surface loam at Menomonie, and residual clay at Halcyon. In using it on calcareous clays caution should be taken to grind them sufficiently fine before molding, and then burn them to a sufficiently high temperature. It is found on looking over the tests of Wisconsin dry-press bricks, that those made from red-burning clays, which are more dense burning than the calcareous ones, give a brick of greater strength.

Drying. The methods of drying commonly employed are open-yard, pallet-racks, and tunnel dryers. Of these three only the first one is usually selected because it involves comparatively little expense; the use of tunnel dryers is however slowly increasing, and has been adopted at nearly all of the larger yards. It also permits operation in cold weather. In this connection, it is necessary to consider the ability of the clay to stand rapid drying without cracking. Most of the siliceous clays, can be dried moderately fast without much danger, but in the case of some of the lake clays or estuarine deposits, much care has to be exercised even in open air drying on pallets, and at many of the yards it is found necessary to have canvass screens to protect the green bricks from the wind (Pl. V, Fig. 1). The

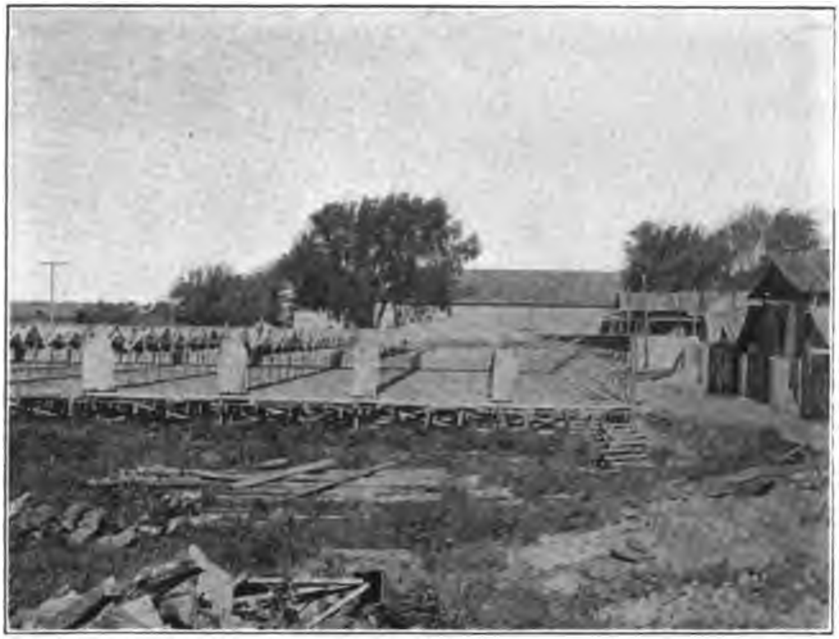


Fig. 1. Drying racks at Whittet's brick yard, Edgerton. The bricks are dried on the racks, which can be covered by canvas screens to prevent rapid drying and cracking.

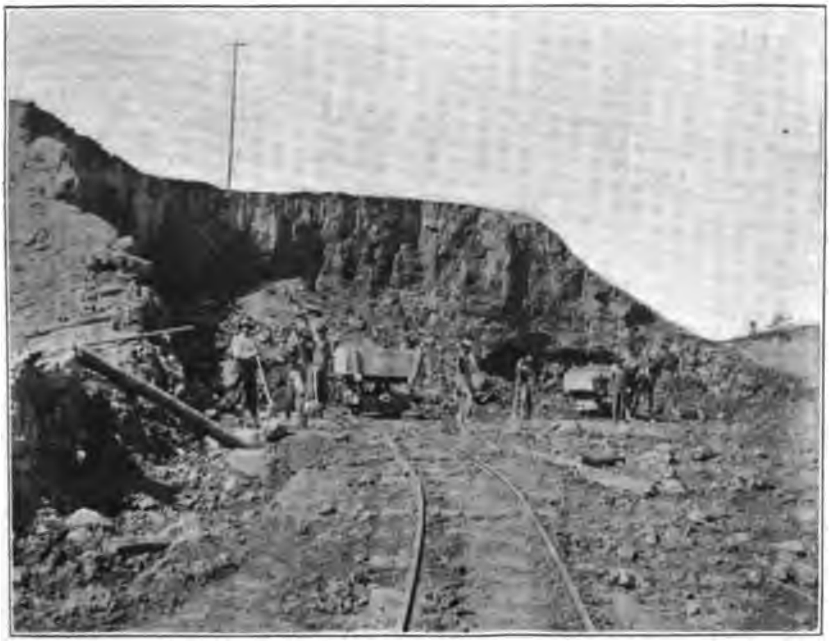


Fig. 2. Bank of Manitowoc Clay Mfg. Co., Manitowoc. The clay is worked by falling and the run of the bank is used. It is loaded on cars which are hauled to the yard.

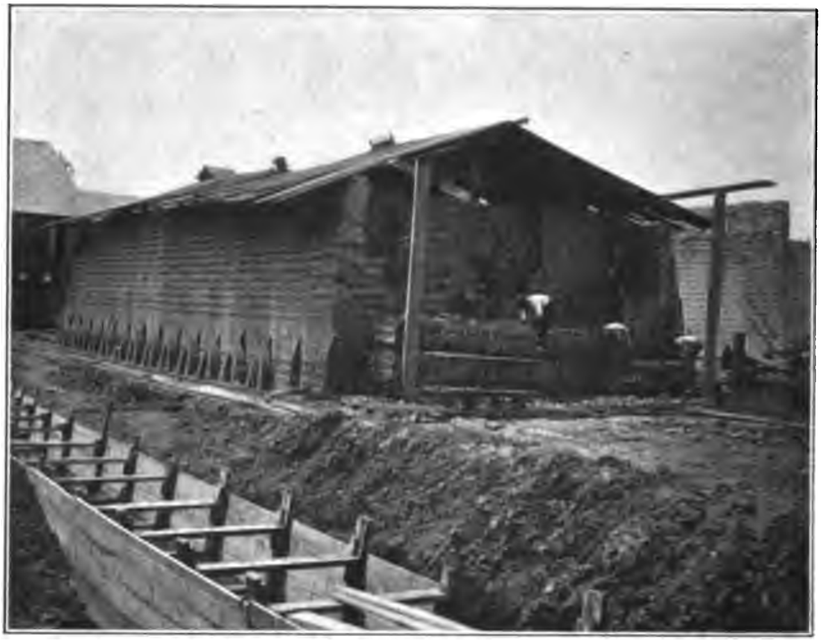


Fig. 1. Setting a scove kiln. This is the type of kiln used at most of the yards. The temporary side and end walls had not yet been placed in position when the view was taken.

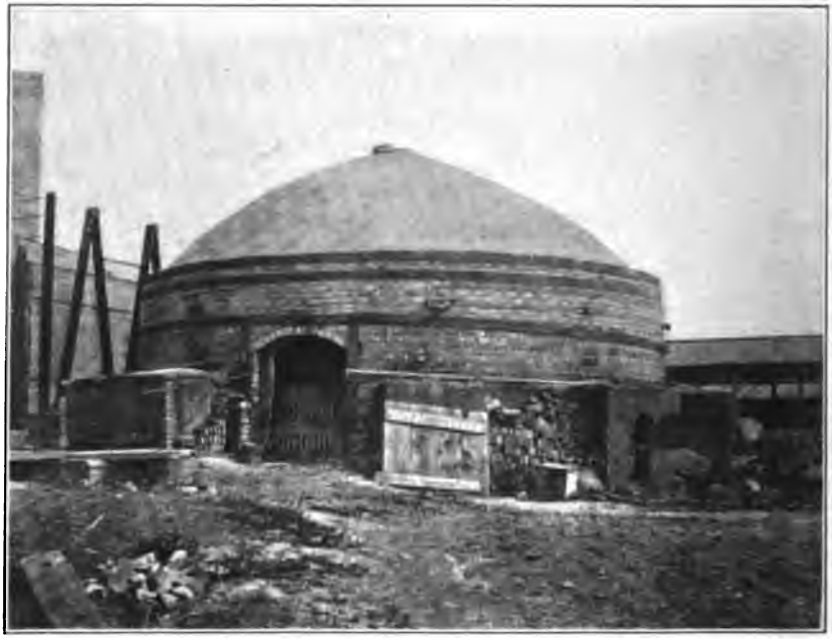


Fig. 2. Circular down draft kiln, Riverside Brick works, Halcyon.

amount of shrinkage that takes place in drying varies considerably, and is greater on the average for soft-mud than stiff-mud brick, as the following figures of measurements made on freshly molded and dried bricks will show.

Per cent air shrinkage.

	Linear.	Cubical.
Stiff mud—		
Edgerton	1.55	6.75
Merrimac	7.14	21.57
Racine	5.74	12.99
Sheboygan	4.22	12.00
Wauwatosa	3.64	21.20
Soft mud—		
Clintonville	9.72	23.77
Edgar	7.57	35.10
Merrill	7.35	26.65
Racine	1.49	11.12
Racine	4.46	11.24
Wausau	4.28	21.03
Whittlesey	8.57	20.80

Burning. Probably five sixths of all the bricks made in Wisconsin are burned in scove kilns, and the remainder in either circular down draft or continuous kilns.

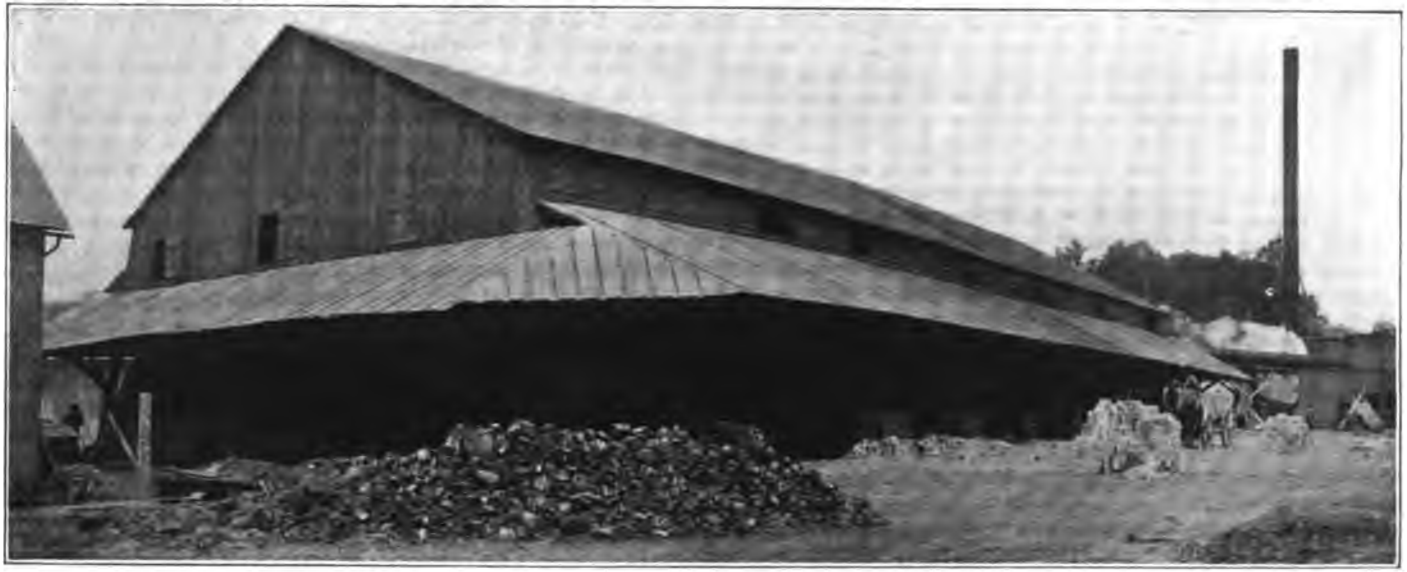
For common brick the scove kiln (Pl. VI, Fig 1.) serves the purpose as well probably as any other, but does not give as uniform results as a closed kiln. They are commonly burned with wood, although at some yards, wood is used for water smoking and coal for the rest of the burning. The temperature reached, is not, as a rule, high, being cone 010 or often less in the red-burning clays, and 1–3 in the case of the cream-burning ones. At some yards a forced draft is obtained, by pumping air into the arches during burning, it being claimed that a saving of fuel is thereby accomplished. While this may be, its use for burning calcareous clays should be made with care, as the writer saw some instances, where the bricks over the arch for a distance of several courses were completely and invariably melted down.

Continuous kilns (Pl. VII) are in use at several Milwaukee yards but the results are not always as uniform as might be desired, a fault which is chargeable perhaps to the construction of the kiln rather than the method of burning. This fact has unfortunately operated to some extent against the spread of the continuous kiln in Wisconsin and before condemning this method of burning, the manufacturer should examine the continuous kilns in use at more than one locality.

The use of permanent walled kilns of either rectangular or circular form, up draft or down draft principle deserves more consideration at the hands of the Wisconsin clay workers than it has hitherto received. The initial expense has no doubt interfered with its introduction but these kilns permit of better control in firing, and give a more uniform product, as well as being more economical of fuel.

Very few of the bricks made in the state are burned to vitrification, and there is consequently but little fire shrinkage in many cases, and sometimes even a slight swelling. The low fire shrinkage is shown by a few measurements made at different yards.

Locality.	Linear Fire Shrinkage.	Cubical Fire Shrinkage.
Stiff-mud:		
Edgerton	0	4.23
Merrimac	—.76	15.24
Port Washington	0	11.38
Racine	1.49	7.49
Sheboygan	2.94	3.37
Wauwatosa	.75	7.12
Soft-mud:		
Clintonville	0	—19.00
Edgar	0	6.75
Merrill	.79	36.24
Racine	1.51	3.23
Racine	—.74	5.89
Wausau	1.49	7.27



Continuous kiln at Burnham Bros., Wauwatosa yard, near Milwaukee.

CHAPTER III.

THE GEOLOGY OF WISCONSIN CLAYS.

This subject has been somewhat fully treated in the report by Dr. Buckley, but it will do no harm to refer to it again briefly in this volume, in order to permit a clearer discussion of certain questions of practical importance.

The clay deposits of Wisconsin can be divided into two great groups, viz., the residual and transported clays.

RESIDUAL CLAYS. These are found at a number of localities in Wisconsin, but are only exposed at those localities where there is little or no covering of later material. The area in which they occur most abundantly is in the central portion of the state, in the counties of Marathon, Wood, Jackson, Clark, and Eau Claire, while in addition to these outliers are known in Marquette, Taylor, and Barron counties. In all of these counties except the last three it is possible to roughly outline an area in which the residual clays *may* be found, but the actual number of recorded exposures is comparatively few. The reason for this scarcity of outcrops is twofold. In the first place the residual clays of Wisconsin are very old geologically, and are not the result of surface decay of the rocks in very recent geological times. They have in part been formed in times earlier than the Potsdam, and the sandstone of the latter age has been laid down over them thus forming a protective cap. The clays cannot therefore be seen unless the roof of Potsdam sandstone is removed. This has occurred at several localities, exposing the clay. In the second place there is throughout the residual area a more or less heavy covering of glacial drift which completely hides the underlying formations. There are also residual clays derived from Potsdam schists, but even these are often heavily covered by glacial deposits.

For these reasons, although the residual clays are very extensive,, they are accessible at but a small number of points. Among the areas known in which they are exposed may be mentioned Ringle, Stevens Point, Grand Rapids, Pittsville, Junction City, Black River Falls, Halcyon, Merillan, and Eau Claire. In outlying districts they are found south west of Medford, near Rice Lake, and northeast of Portage City.

In searching for these clays, a careful examination should be made along the streams, and other depressions, and when a deposit is found it should be carefully exploited by boring or test pitting, for the reason that residual clays often show considerable variation in depth. Where the clay occurs under the sandstone it will probably not pay to work it unless the latter is very thin.

Since the clays of this group have been derived from a number of different rock types, and the parent rock exerts more or less influence on the clay, the residuals of Wisconsin can be expected to show more or less variation from place to place.

Some residual clay is found in southwestern Wisconsin, in the areas of Galena limestone, from which it has been formed but the material is very stony, and not considered in this report.

TRANSPORTED CLAYS.* Those found in Wisconsin include glacial clays, marine clays, lake or lacustrine clays, estuarine clays, and loess clays of doubtful origin.

Glacial clays. These are scattered over a large portion of the state, and present several types. The most common form is a shallow deposit, which often occupies depressions, and is of rather sandy character, or consists of laminae of clay and clayey sand. These have usually been deposited in lakes that occupied basin-shaped depressions or were formed by the temporary damming of valleys, and hence are thicker in the center and thin out around the borders. In a few instances, as around Menomonee, they show considerable thickness. The section of the bed is subject to variation from point to point. Few of them are of great extent, but in any one area there may be a group of deposits, easily accessible from some one plant, and whose combined contents are large.

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*For the origin of these see Chapter I.

A second sub-type is that known as boulder clay, which is tough, dense, stony material, often containing large boulders, that are thrown out in working the clay. Deposits of this class should be avoided as far as possible.

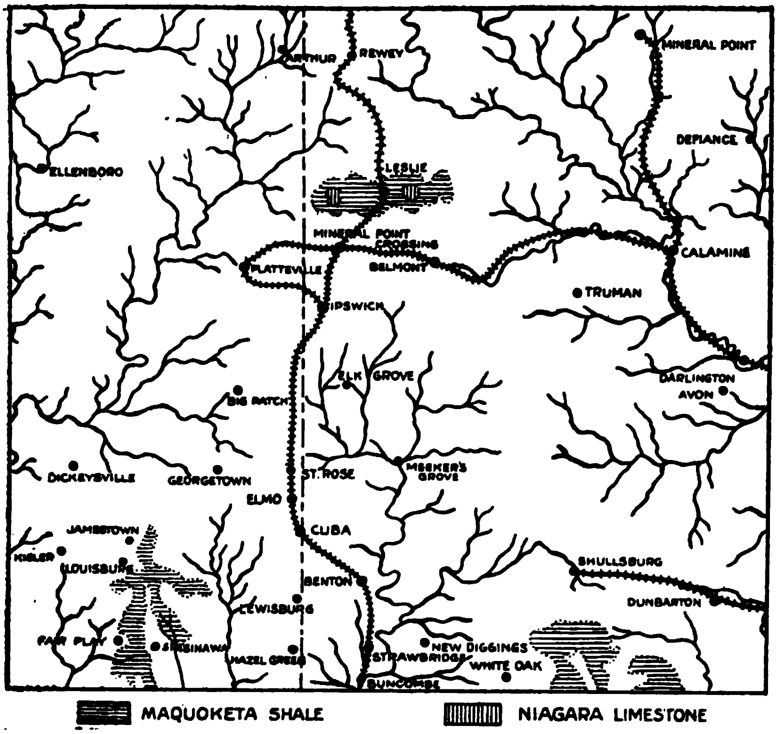

FIG. 4.—Map showing distribution of Maquoketa shale.

Marine clays. These are represented by the Cincinnati shale of eastern Wisconsin and the Maquoketa shale of southwestern Wisconsin. The former occurs as a belt extending from Sturgeon Bay, southwestward through Stockbridge, Oakfield, and Eagle. In general it is a calcareous shale, containing occasional layers of limestone, and weathers to a very plastic clay. The shale according to Buckley* is from 165 to 240 feet thick. Although it underlies the belt mentioned above, still it is not exposed continuously. In order to produce the best results in brick manufacture it is necessary to mix the fresh shale with the weathered part, or if the latter is not available the shale should be allowed to weather somewhat first. In the southwestern part of Wisconsin the Maquoketa shale is to be looked for in the area outlined on the map Fig. 4. There it is a somewhat calcareous shale, containing scattered bands of limestone which can be thrown out in mining. The upper portion of the shale is mellowed to a very plastic yellowish clay, which burns to an excellent, dense, red body at a low cone.

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*Bul. Wis. Geol. and Nat. Hist. Survey, VII, Pt. I, p. 35.

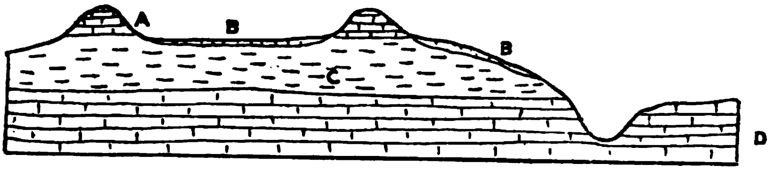

FIG. 5.—Section showing Maquoketa shale and limestone mounds. A, Niagara limestone; B, Loess; C, Maquoketa shale; D, Galena limestone.

Another less desirable clay, is found below the surface loess, in the region surrounding the Maquoketa shale areas, and has been formed by the decay of the cherty Galena limestone. Around the borders of the Maquoketa area the two are no doubt slightly intermixed.

Lake or lacustrine clays. Although these cover but a comparatively small portion of the entire area of Wisconsin (Pl. II), they form nevertheless one of the most important clay resources of the state, for the reason that the deposits are of great extent and thickness. They underlie large areas in Door, Kewaunee, Oconto, Outagamie, Waupaca, Calumet, Winnebago, Waushara, Manitowoc, Sheboygan, Milwaukee, Racine, and Kenosha counties in eastern Wisconsin, and a large tract in Ashland, Bayfield, and Douglas counties of northwestern Wisconsin. Although forming a continuous belt along the shore of Lake Michigan, the width of it is somewhat variable.

In Racine county according to Buckley* the lacustrine deposits extend eighteen miles west of the present shore line; in Ozaukee county they narrow down to two or three miles, but widen again to the northward, and maintain their width all the way up into Door county. Their greatest width however is in the region west of Green Bay and Lake Winnebago.

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*Op. cit., p. 36.

Wherever found they usually show a great thickness, and most of the larger plants in the state are located on them.

The lake clays vary from laminated beds, to massive silty deposits; they are usually red or reddish brown in their upper portion, and gray, blue or greenish below. Not infrequently there is a capping of several feet of gravel and loam on them, while the clay itself may contain masses of sand, boulder clay, or streaks of limestone pebbles, and these impure spots are either left standing in digging the clay, or else are thrown to one side in mining.

On account of the thickness and extent of the lacustrine beds, they can be worked with a steam shovel provided the size of the plant warrants it, but this method of digging is only economical where the machine can be kept in constant operation. It would not be practical where a separation of the several beds or benches in a bank is necessary. Where a steam shovel is employed, the gravelly overburden is first removed with pick and shovels.

The lacustrine clays are mostly cream-burning and the cream brick made from them at Milwaukee have long been well known. At not a few localities the upper part of the bank is red-burning, this being due probably to the fact that the lime has been leached out of the upper few feet of the clay. With such conditions it is possible to make both red and cream bricks at some yards.

Estuarine clays. At the time the lake clays were being deposited, many of the river valleys then existing were so deeply flooded as to practically become estuaries of the great lakes, which were then far more extensive than they are now. Much clay was deposited in the quiet water of these estuaries, giving rise to a type of deposits included under the head of estuarine clays. Owing to the mode of their formation the deposits will be found in belts along the lines of drainage, and although distributed over a considerable area, do not form a bed of more or less unbroken extent as might perhaps be inferred from the map in Plate II. At many points where they are worked, the beds are found underlying a flat tract, bordered by sand hills, the section being somewhat as indicated in Fig. 3.

The estuarine deposits as mentioned by Buckley* are found along the Fox, Wolf, Rock, Wisconsin, Eau Claire, Chippewa, Black, Red Cedar, and other rivers in the eastern and southeastern parts of the state.

The estuarine clays are mostly thinly laminated, and have a maximum thickness of from fifty to one hundred feet.*

They also vary more in their composition than do the lacustrine clays, the variation in their calcium contents being specially noticeable. Owing to their proximity to streams, trouble is sometimes experienced with water seeping into the pit. Like the lacustrine clays they may show both red and cream-burning layers in the same bank.

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*Op. cit., p. 37.

**Ibid*, p. 37.

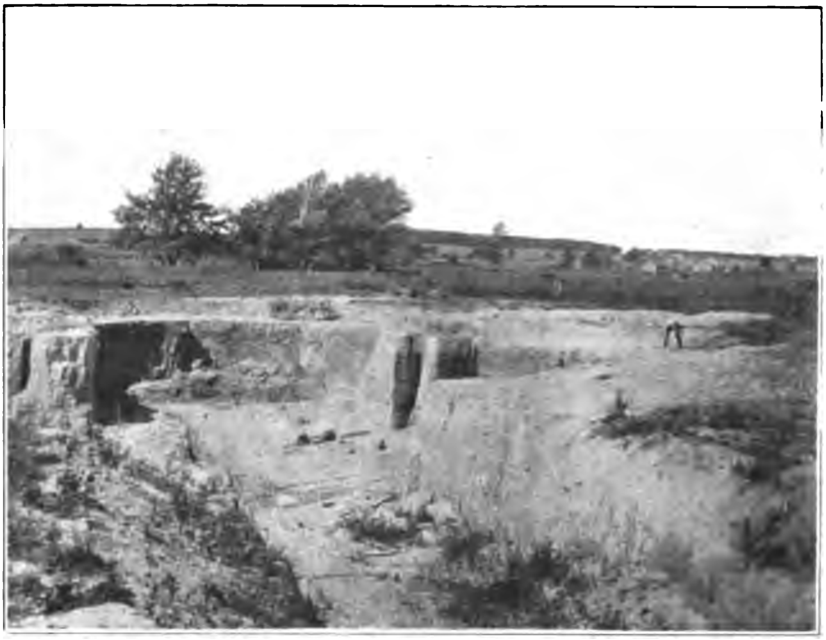


Fig. 1 Clay pit, Whittet's yard, Edgerton. A horizontally stratified estuarine clay and, like many others of this type, underlies a flat area surrounded by sand hills, which are seen in the background.

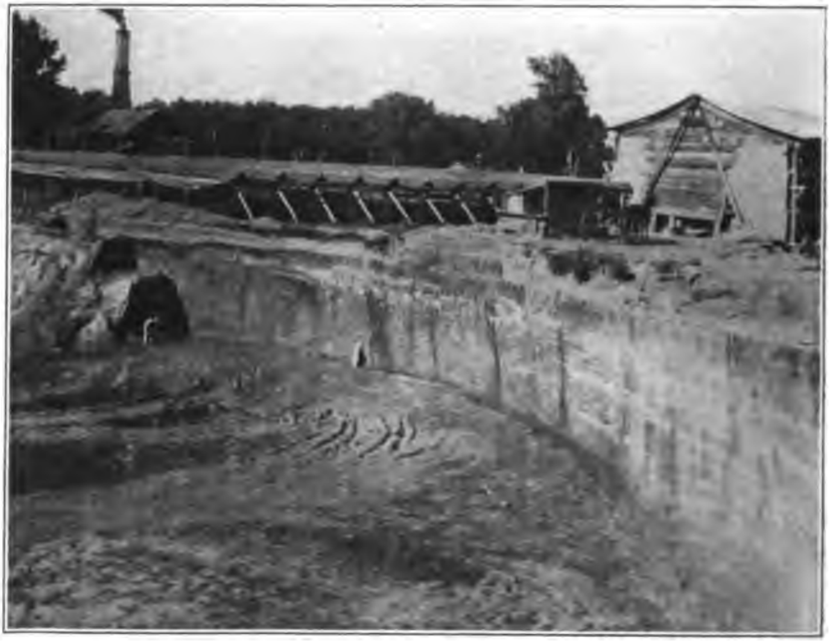


Fig. 2. Sanborn's clay bank and brick yard, Portage City.

CHAPTER IV.

THE WISCONSIN CLAYS, THEIR USES AND PROPERTIES.

On the preceding pages brief reference has been made to the geology of the Wisconsin clays, and the distribution of each type. In the present chapter there will be given the detailed results of the laboratory tests made on the samples collected in the field. For practical purposes it seems more desirable to group the clays in this chapter according to their physical properties. Under each of the sub-groups, the different occurrences are taken up as far as possible in geographical order.

The subdivisions thus made are:

I. Buff or cream-burning, calcareous clays.

II. Red or brown-burning clays.

III. White-burning clays of refractory character.

IV. Slip clays.

1. CREAM-BURNING CALCAREOUS CLAYS. These occupy a large area in the eastern and southeastern portion of the state, and a small area in the northwestern part, as mentioned under estuarine and lake clays. In addition there are a number of scattered deposits of glacial origin, as well as some shaly beds belonging to the Cincinnati shale.

The occurrences belonging to the several formations are not separated, but the discussion of all cream burning deposits is taken up in geographic order from west to east, and from south to north. In some cases where a red-burning clay overlies the cream-burning one, the tests on it are included in this group, but a cross reference is made to it under its locality in the discussion of the red-burning clays.

DETAILED DESCRIPTION OF OCCURRENCES.

Monroe, Green Co. There are two yards at this locality, one of these is operated by Kuster, Bowman and Schober, and the other is worked by F. Freeze. The former is mentioned under the red-burning clays. At Freeze's yard the section involved is loam 2 feet, yellowish red-burning clay 8 feet, blue clay (white-burning) 2 feet. The red clay in the middle of the section is very similar to that at the other yard but less sharply laminated. Near the bottom of the bank just above the blue clay there are several layers of limonite which are thrown out in working the pit. The blue clay (Lab. No. 1044) which is of silty character works up with 22 per cent of water to a mass of good plasticity. In burning it behaved as follows:

Wet-molded bricklets:				
Cone	010	05	03	1
Fire shrinkage	0	.3	.6	.6
Color	light buff	cream	cream	buff
Absorption	32.58	35.70	36.29	34.67

It can be seen from these tests that the material is very gritty, of very low shrinkage, and high porosity so that it is probably used for making a common brick.

Uses. The clay is now being used for brick manufacture and both cream and red brick are made from the different layers in the bank. The material is tempered in a soak pit, molded in a horse-power soft mud machine, dried on racks and burned either in a scove kiln or a round down draft kiln.

Edgerton, Rock Co. The cream-burning estuarine clays have been opened up on the southwest side of the railroad a few yards west of Edgerton depot and adjoining the brick yard of Whittet Bros. (Pl. VIII., Fig. 1). This section involves:

Red clay	3 to 4 feet
Blue clay	9 feet
Gravelly bottom clay	....

The top clay (Lab. No. 1028) is said to stand less fire than the bottom clay and shrinks more in burning, but the lower is the one chiefly used. Its physical properties were as follows: Soluble salts, .24; slaking moderately fast, plasticity excellent; grit low. It worked up with 22 per cent of water, and had an air shrinkage of 8.5 per cent. Its average tensile strength was 228 pounds per square inch with a maximum of 260 pounds per square inch. In burning it behaved as follows.

Wet-molded bricklets:						
Cone	010	05	03	1	2	3
Fire shrinkage	.3	sl. sw.	sl. sw.	0	2.3	3.3
Color	buff	cream	cream	light buff	light buff	light buff
Absorption	29.15	30.11	30.43	25.77	24.51	23.86

It burns steel hard at cone 2 but gives a sufficiently hard body for bricks at a lower temperature. In burning the clay does not deepen perceptibly even up to cone 2. The large brick crack badly when dried rapidly and on this account care has to be taken in air drying the product.

The material is used at the present time for the manufacture of common brick and in making brick a mixture of the run of the bank is used together with one-half yard of sand per thousand brick. The bricks are molded on a stiff-mud machine, dried under sheds, protected from the wind, and burned in Dutch kilns. The blue clay alone works best for drain tile, for the presence of the red clay tends to make it tear in molding.

The top clay is said to shrink more in burning but does not burn to as light a cream in color and the difference in size and hardness in bricks made from the two different kinds of clay is quite noticeable. The average burned bricks made from the run of the bank are considerably softer. The bricks made from the top clay on account of their greater density and hardness are sold for pavements.

Whitewater, Walworth Co. Here again the estuarine clays are employed for brick manufacture at the yard of the Whitewater Brick and Tile Company. The clay bank, which is a rather shallow excavation, lies on the north side of the yard and is part of a large deposit underlying a large area which is surrounded by small sand hills. Borings in the clay have shown it to have a depth of 25 to 30 feet, and to be underlain by sand. The clay contains occasional sand streaks as well as lime pebbles. The material as dug is not used for the manufacture of brick but about 10 per cent sand is mixed in with it, this being obtained from the hill to the east of the yard. The general physical properties of the clay and brick mixture are given in parallel columns for purposes of comparison.

Material	Run of bank	Brick mixture
Lab. No	1,010	1,011
Color	brown	yellow brown
Soluble salts	.22	.20
Water required	22	19.8
Slaking	moderately fast	slowly
Plasticity	good	high
Grit	some	medium
Air shrinkage	6.24	6.5
Average tensile strength	246	316
Maximum tensile strength	310	355
Wet-molded bricklets—		
Cone 010:		
Fire shrinkage	.4	.4
Color	cream	pink buff
Absorption	28.17	23.23
Cone 05:		
Fire shrinkage	.7	s. s.
Color	cream	cream
Absorption	28.62	22.63
Cone 03:		
Fire shrinkage	.7	0
Color	light buff	cream
Absorption	25.81	20.63
Cone 1:		
Fire shrinkage	10.3	2.7
Color	buff	light buff
Absorption	8.18	16.35
Cone 2:		
Fire shrinkage		3.5
Color		cream
Absorption		13.89
Cone 3:		
Fire shrinkage		4
Color.		cream
Cone 5:		
Fire shrinkage		viscous
Dry-pressed bricklets—		
Cone 05:		
Fire shrinkage	0	0
Color	light buff	buff
Absorption	34.22	
Cone 1:		
Fire shrinkage	8.66	
Color	light buff	
Absorption	16.57	

Chemical composition.

Silica (SiO_2)	32.48	42.28
Alumina (Al_2O_3)	7.31	8.26
Ferric oxide (Fe_2O_3)	4.37	3.84
Lime (CaO)	18.44	13.05
Magnesia (MgO)	7.18	6.01
Potash K_2O)	2.01	2.51
Soda (Na_2O)	.48	.49
Titanic acid (TiO_2)	.12	.05
Loss on ignition	27.70	22.07
Total	100.09	100.56
Total fluxes	32.48	25.90

It is interesting to compare the tests of these two clays. It will be noticed that owing to the much higher percentage of lime carbonate in the clay than there is in the brick mixture, that the former burns to a more porous body, but it also has a lower fusing point, lower tensile strength, and a higher shrinkage at cone 1 because its point of viscosity is being approached. A large brick made from the clay shows that it stood rapid drying without cracking while the brick mixture did not seem to stand as fast drying as the raw clay.

Uses. The material at the time of the writer's visit was being employed for the manufacture of common cream-colored brick. The clay is prepared by passing it through rolls, then through a stiff-mud end-cut machine. The bricks are dried in long sheds with steam pipes underneath, while the burning is done in a circular down-draft kiln, at cone 1. In this the bricks are set about 25 courses high and show a settle of 4 to 6 inches. Some tile are made, but for these the sand is left out, the clay alone being employed.

Elkhorn, Walworth Co. The calcareous clays located at this point have been worked by the Elkhorn Brick and Tile Company for the manufacture of brick and drain tile. For making brick the run of the bank is used, while for the manufacture of tile the more plastic or lower beds of the bank have been employed. The tests of these two bring out quite well the different physical qualities that can be obtained by using either certain layers of the bank or a mixture of the section and for purposes of comparison the two are given below.

Material	Drain tile mixture	Brick mixture, run of bank.
Laboratory No	1061	1062
Water required	19.8	19.8
Slacking	slow	moderately fast
Plasticity	good	good
Grit	very little	much, silty
Air shrinkage	5.5	2.9
Average tensile strength	....	206.4
Maximum tensile strength	....	236
Wet-molded bricklets—		
Cone 010:		
Fire shrinkage	.3	.7
Color	pink red	pink
Absorption	22.08	29.92
Cone 05:		
Fire shrinkage	sl. sw.	sl. sw.
Color	buff	pale buff
Absorption	21.03	33.86
Cone 03:		
Fire shrinkage	sl. sw.	sl. sw.
Color	cream buff	light buff
Absorption	19.08	31.75
Cone 1:		
Fire shrinkage	5.7	sl. sw.
Color	yellow buff	buff
Absorption	5.57	29.57
Cone 2:		
Fire shrinkage	6.5	1
Color	Greenish yellow	buff
Absorption	4.42	27.94
Cone 3:		
Fire shrinkage	7	1.6
Color	greenish buff	deep buff
Absorption	3.27	26.90
Steel hard	cone 03	above cone 3
Viscous at	5	

The tile clay gives a good hard body while the brick mixture which is a very sandy porous clay shows a curiously high tensile strength considering its silty character. This same property also causes it to burn to a very porous body.

Kenosha, Kenosha Co. Cream-burning brick clays are worked at this locality in the yard of W. J. Craney. The section involves:

Soil	18 in.
Deep red clay	7 ft.
Blue or cream-burning clay	6 ft.

The properties of the two are as follows:

Material	Lower blue clay	Upper red clay
Laboratory No	1072	1073
Color, moist	brown	brown
Soluble salts	.45	.27
Water required	17.6	25.3
Slaking	slow	fast
Plasticity	high	high
Grit	none	very little
Air shrinkage	4.5	8.2
Average tensile strength	64	299.6
Maximum tensile strength	72	332
Wet-molded bricklets—		
Cone 010:		
Fire shrinkage	sl. sw.	.3
Color	light brown	red brown
Absorption	36.75	18
Cone 05:		
Fire shrinkage	sl. sw.	2.6
Color	light brown	yellow red
Absorption	30.98	15.17
Cone 03:		
Fire shrinkage	sl. sw.	2.7
Color	light pink buff	red brown
Absorption	26.28	9.87
Cone 1:		
Fire shrinkage	....	viscous
Color	....	brownish gray
Cone 2:		
Fire shrinkage	sl. sw.	
Color	yellow buff	
Absorption	24.96	
Cone 5:		
Fire shrinkage	viscous.	
Dry-press bricklets—		
Cone 05:		
Fire shrinkage	1.33	
Color	light buff	
Absorption	28.19	
Cone 1:		
Fire shrinkage	3.33	
Color	light buff	
Absorption	24.52	

Chemical composition.

Silica (SiO_2)	38.62	55.41
Alumina (Al_2O_3)	8.75	18.10
Ferric oxide (Fe_2O_3)	8.22	5.91
Lime (CaO)	14.04	6.28
Magnesia (MgO)	6.27	.14
Potash (K_2O)	2.65	1 54
Soda (Na_2O)	.89	.49
Titanic acid (TiO_2)	.07	.25
Loss on ignition	19.99	12.34
Total	99.50	100.46
Total fluxes	32.07	14.36

A large brick made of the blue clay stands rapid drying fairly well but the clay does not burn steel hard until cone 2. The upper red clay gives a good hard brick even at cone 010 but does not burn to a very good color and the clay is not as homogeneous in its color burning qualities as the preceding sample.

The difference in tensile strength is most noticeable, as is also the difference in shrinkage and fusibility. The upper red clay on account of its easy fusibility makes a fair grade of slip, burning to a deep brown glaze at cone 6.

Uses. The clay which is finely stratified has been used in the manufacture of common brick in the proportion of one half red top clay and half lower blue clay. The material is run through a crusher and molded in a soft-mud machine, and dried in hacks on the yard. The brick are burned in scove kilns.

Racine, Racine Co. This is one of the most important brick making localities in the state there being a number of good banks located along the lake shore north of Racine, and also at North Point 4 miles north of the town, as well as on the southeastern edge of the town. The section in nearly every bed shows a cream-burning clay overlain by the gravelly sand or gravelly loam and just north of town on Main street the section usually shows about 2 feet of sand and gravel underlain by 6 to 8 feet of buff-burning clay which in turn rests on a sticky clay that is not used. At North Point the section of the clay bank at the time of the writer's visit showed

Soil	6 in.
Coarse loamy sand	1 to 3 ft.
Purplish clay	6 to 8 ft.

The tests made on the several clays are given side by side after which they are discussed comparatively.

Locality	North Point Yard.	Cedar Bend Yard.	Lake Shore Yard.
Lab. No	1103	1105	1115
Soluble salts	.33	.18	.21
Water required	19.8	19.8	17.6
Slaking	fast	fast	fast
Plasticity	good	good	good
Grit	fine	mixed	much. fine
Air shrinkage	7.6	6.3	4.8
Average tensile strength	276.3	....	
Maximum tensile strength	310	....	
Wet-molded bricklets—			
Cone 010:			
Fire shrinkage	sl. sw.	.6	sl. sw.
Color	pink buff	light red	pink buff
Absorption	20.98	21.41	19.25
Cone 05:			
Fire shrinkage	.7	.8	0
Color	cream	light red	cream
Absorption	20.70	21.39	19.33
Cone 03:			
Fire shrinkage	.3	0	.6
Color	cream	dark buff	buff
Absorption	20	20.21	17.85
Cone 1:			
Fire shrinkage	4.6	7	3
Color	cream	buff	light gray buff
Absorption	8.70	5.15	13.09
Cone 3:			
Fire shrinkage	6	....	5.6
Color	buff	....	gray buff
Absorption	....	....	4.25
Dry-press bricklets—			
Cone 1:			
Fire shrinkage	4.33	....	.66
Color	greenish buff	....	buff
Absorption	20.30	....	22.34
Cone 5:			
Fire shrinkage	viscous	....	
Steel hard	cone 3	cone 1	cone 1

The Cedar Bend clay is less calcareous than the others and hence burns a different color. There is not much difference in the porosity to cone 1, at which temperature the clay mentioned shows a higher sshrinkage and lower absorption.

Chemical composition.	1115
Silica (SiO_2)	47.36
Alumina (Al_2O_3)	6.98
Ferric oxide (Fe_2O_3)	6.68
Lime (CaO)	13.10
Magensia (MgO)	4.36
Potash (K_2O)	1.28
Soda (Na_2O)	0.68
Titanic acid (TiO_2)	.14
Loss on ignition	19.05
Total	99.63
Total fluxes	26.10

Uses. These clays are used at the present time for the manufacture of common brick and the product produced is one of the hardest made in the state, although it requires a higher temperature to burn it than that needed in many other localities where similar types of clay are employed. The one interesting feature connected with the manufacture in this region is that several different processes of molding are employed. Thus at the North Point yard the clays are molded in a stiff-mud machine, receiving their preliminary preparation in rolls and a pug mill, while they are dried in the sun and burned in Dutch kilns. A mixture of 1-3 sand and 2-3 clay is used.

At the yard just north of Racine the clay is tempered in ring pits or pug mills operated by horse power and molded in soft-mud machines, while at the Cedar Bend yard the clay is molded soft-mud and then repressed.

The strength of the three are as follows:

	Crushing strength.	Transverse.	Absorption.
Stiff-mud	....	....	....
Soft-mud	....	....	....
Soft-mud repressed	....	....	....

The burning at the yard just north of the town is done in scove kilns, while at Cedar Bend the bricks are burned in Dutch kilns. At the North Point yard a temperature of Cone 1 is reached.

Burlington, Racine Co. Here again cream-burning clays are worked at the yard of the Burlington Brick and Tile Company of which Mr. William Meadow is the manager. The clay pit which is located near the yard shows the following section:

Stripping	2½ feet
Red clay	2 feet
Sand (used with the clay for brick and tile)	1 foot
Blue clay	3 feet
Red gravel (water bearing).	

The various layers in the bank are quite distinct, although not sharply marked and those on the upper part are quite strongly laminated as well as being tinged with iron oxide. The blue clay is quite tough and contains occasional pebbles.

In making the bricks they find that the blue clay has a greater shrinkage than the red, as confirmed by the laboratory tests.

The physical properties of the two clays were as follows:

Laboratory No	1052	1051
Material	upper clay.	lower blue clay
Color, moist	yellow brown	....
Water required	22	30.8
Slaking	slow	....
Plasticity	high	high
Grit	variable	none
Air shrinkage	7.3	9.1
Wet-molded bricklets—		
Cone 010:		
Fire shrinkage	1.3	1.6
Color	buff	pink buff
Absorption	21.97	22.87
Cone 05:		
Fire shrinkage	1.3	1.6
Color	buff	bink buff
Absorption	19.85	23
Cone 03:		
Fire shrinkage	1.3	7.3
Color	buff	buff
Absorption	19.43	13.60
Cone 1:		
Fire shrinkage	2	
Color	yellow buff	viscous
Absorption	14.33	
Cone 2:		
Fire shrinkage	2.7	
Color	yellow buff	
Absorption	13.37	
Cone 3:		
Fire shrinkage	2.7	
Color	greenish buff	
Absorption	13.15	
Cone 5:		
Fire shrinkage	viscous	
Steel hard	05	

Chemical anaylsis.

Silica (SiO_2)	41.86
Alumina (Al_2O_3)	14.31
Ferric oxide (Fe_2O_3)	6.69
Lime (CaO)	9.38
Magnesia (MgO)	4.75
Potash (K_2O)	3.73
Soda (Na_2O)	.92
Titanic acid (TiO_2)	.05
Loss on ignition	17.86
Total	99.55
Total fluxes	25.47

The lower blue clay is a very fine-grained clay and one of the most easily fusible of the entire series tested, but it burns to a good hard body at 05 while the top clay is quite gritty, but also gives a good buff body at 05 with a low shrinkage up to cone 1. The color deepens considerably at cone 3.

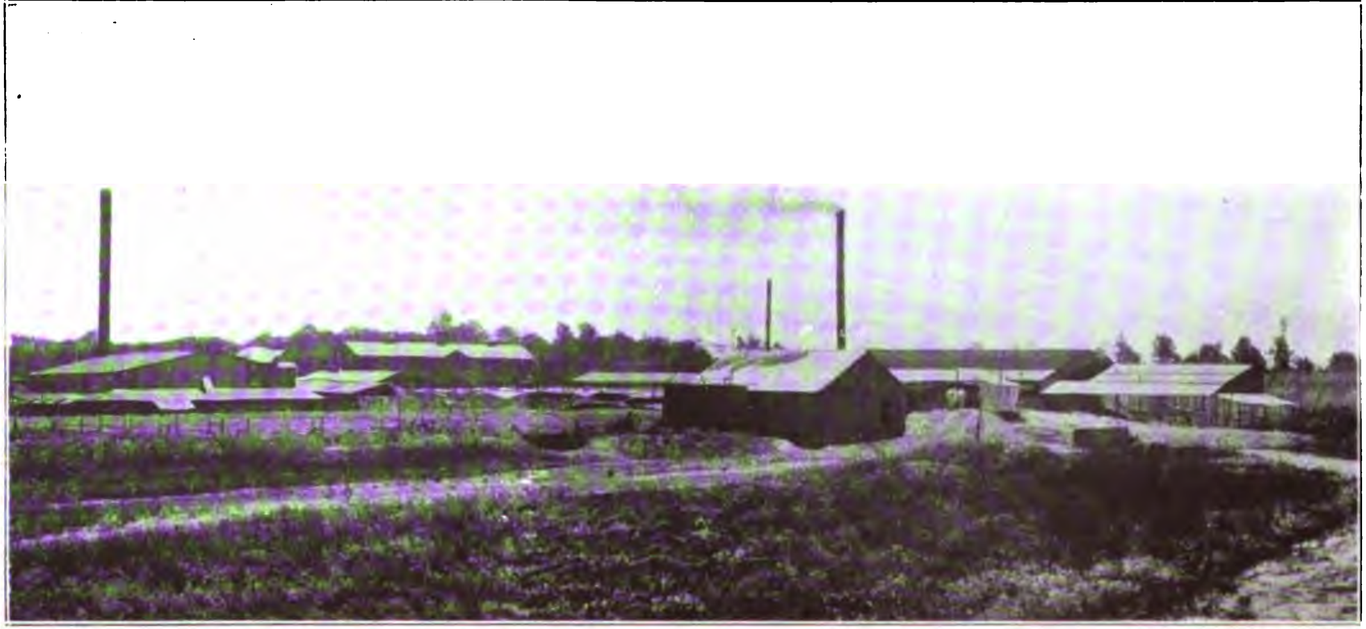
Uses. The clay is used for the manufacture of both brick and tile. For the former the clay is tempered in a soak pit and then put through a stiff-mud machine. The brick and tile are dried on pallets the former being burned in scove kilns and the latter in down draft kilns at 04.

Madison, Dane Co. Clays are worked at D. Stevens' yard 2 miles west of the city. The section of the bank shows:

Loam	1 ft.
Coarse sand	8 ft.
Red clay with limonite streaks	8 ft.
Blue clay	10 ft.

The top clay is red-burning while the lower clay is cream-burning as can be seen from the following tests. The tests of the top clay are nevertheless put in here for purposes of comparison.

Material	Top clay	Lower clay
Lab. No	1064	1116
Soluble salts	.12	.19
Water required	22	19.8
Slaking	moderately fast	fast
Plasticity	good	fair
Grit	variable	mixed
Air shrinkage	5.1	5.6
Average tensile strength	294.6	
Maximum tensile strength	339	



Burnham Bros., Howell Ave. yard, Milwaukee.

Wet molded bricklets—		
Cone 010:		
Fire shrinkage	0	.7
Color	light red	deep pink
Absorption	16	21.72
Cone 05:		
Fire shrinkage	.3	0
Color	yellow brown	cream
Absorption	15.90	22.08
Cone 03:		
Fire shrinkage	1.7	1
Color	light red	cream
Absorption	13.19	20.54
Cone 1:		
Fire shrinkage	7	
Color	red brown	
Absorption	1.90	
Cone 3:		
Fire shrinkage	vis. beg.	3.4
Color	....	cream
Absorption	....	14.72
Steel hard	cone 3	vis. at 5

The first of these clays is a rather porous material which however burns to a good red body but should not be burned much above cone 03. While the lower cream-burning clay gives a hard body and even at cone 010 gave a good hard brick, although its fusion point is higher than that of the red clay.

Uses. The clays are used for the manufacture of common brick and the run of the bank of either the blue or the yellow is selected, to this about 1-4 sand being added. There are occasional lime pebbles in the clay but these tend to occur in pockets rather than uniformly scattered through the mass. The clays are worked in a soft-mud machine and burned in scove kilns.

Jefferson, Jefferson Co. The estuarine clays have been developed around this locality and are being worked at two yards, viz., that of the Jefferson Brick and Tile Co., and the other that of Kemmeter Bros., but at the present time both are controlled by the same firm. At the former works the character of the clay is fairly well shown because an extensive although shallow excavation has been made. One result of this has been to bring out the horizontal variation in the character of the material. The working face which is about 6 feet high shows a bluish laminated clay at the western end of the bank, while at the north side the material dug is termed a yellow clay and although more sandy than the blue is really nothing more than a weathered phase of it. At both points the clay is overlain by about a foot of black soil. At the south side of the bank there is another pit which shows a blue clay overlain by from 1 to 2 feet of coarse yellow sand which in turn is covered by a thin layer of soil. The blue clay is harder and more brittle when dried, as well as more strongly laminated than the yellow clay.

A still more plastic, finer-grained phase adapted to drain tile is obtained from the northeast end of the yard, and at the same level as the clay in the first part of the excavation mentioned. The general characters of the blue and the yellow clay are as follows:

Material	Yellow clay	Blue clay
Laboratory number	1015	1016
Water required	17.6	22
Slaking	fast	moderately fast
Plasticity	good	good
Grit	in mod. amount	little, fine
Air shrinkage	4.6	6 2
Average tensile strength	252	
Maximum tensile strength	292	
Wet-molded bricklets—		
Cone 010:		
Fire shrinkage		0
Color		buff
Absorption		30
Cone 05:		
Fire shrinkage	sl. sw.	sl. sw.
Color	deep buff	light buff
Absorption	31.54	32.06
Cone 03:		
Fire shrinkage	sl. sw.	sl. sw.
Color	buff	cream
Absorption	31.71	31.20
Cone 1:		
Fire shrinkage	.4	2
Color	light buff	light buff
Absorption	32.47	26.88
Cone 2:		
Fire shrinkage		2.3
Color		cream
Absorption		24.83
Cone 3:		
Fire shrinkage		5.7
Color		light brown buff
Absorption		27.73

No. 1015 when molded into a large brick and dried rapidly shows a slight tendency to crack and the same is true of the blue clay which is very dense but burns to a good cream body, although not as dark-burning as that from Whitewater. While it gives a good hard brick the latter is not by any means dense as can be seen from the absorption tests given above.

Uses. These clays are being exclusively used at the present time for the manufacture of common brick and drain tile. At the yard of the Jefferson Brick and Tile Works the material is prepared in soak pits, molded in soft-mud machines, dried on hacks on the yard and burned in a scove kiln. For brick-making equal proportions of the blue and yellow were taken and mixed with about 12 per cent of sand, while the blue clay alone is used for tile. If the blue clays are used alone it is claimed that they show a tendency to swell and will not burn to a good hard brick, but the reason for the latter is probably due to their being burned at too low a temperature. This is one of the few yards in Wisconsin at which forced draft is used for burning but here it is employed only during the water smoking. The tile are burned in a circular down draft kiln.

At the second yard, namely that of Kemmeter Bros. the clay in its general appearance and burning qualities as judged from the general character of the ware is very similar to that of the first yard and the process of manufacture is quite similar.

Watertown, Jefferson Co. The estuarine clays are worked here and the bank shows the following section.

Black loam	1 ft.
Yellow clay	7 to 8 ft.
Blue clay	25 ft.

The lower clay is not worked, however, to a depth of much more than 8 feet.

As can be seen from the following tests better results are obtained by using a mixture than by using the blue clay alone. The properties of the two were:

Material	Blue clay	Brick mixture
Lab. No.	1063	1111
Soluble salts		.27
Water required	20.9	17.6
Slaking	slow	slow
Plasticity	excellent	high
Grit	little	some, coarse
Air shrinkage	7.1	4.5
Average tensile strength		233
Maximum tensile strength		252
Wet-molded bricklets –		
Cone 010:		
Fire shrinkage	0	.3
Color	gray	light buff
Absorption	29 24	21.85
Cone 05:		
Fire shrinkage	sl. sw.	.3
Color	cream	cream
Absorption	31.12	24.16
Cone 03;		
Fire shrinkage	sl. sw.	0
Color	cream	cream
Absorption	31.64	22.15
Cone 1:		
Fire shrinkage	sl. sw.	2.3
Color	cream	cream
Absorption	29.51	17.31
Cone 3:		
Fire shrinkage	2	4.4
Color	light buff	buff
Absorption	27.47	16.85
Dry-press bricklets—		
Cone 1:		
Fire shrinkage		sl. sw.
Color		cream
Absorption		27.41

Comparison of the properties of the two sets of clays show that the main points of difference are, lower air shrinkage, and greater density in the brick mixture, while the clay alone swells in burning.

The clay alone is a porous, finely silty material, which burns to a good cream body. The mixture when dried is coarse grained and shows scattered mica scales.

Uses. The clay which underlies a considerable area in this region is used at the works of L. H. Cordes & Co. for making common brick.

The material is put through rolls and then dumped into the soak pit together with the requisite amount of sand. The quantity being used is one load of sand to two loads of clay. The molding is done in soft-mud machines. The bricks are dried in hacks on the open yard. Scove kilns are used for the burning. The mixing of the clay is not very carefully done and the product consequently shows some variation in size, even in the air dried material. They claim that in burning there is no swelling of the product but it probably occurs, although so slight that they have not noticed it.

Fort Atkinson, Jefferson Co. The estuarine clays have been opened up to the east of town where they are found underlying a flat area bordering the Rock River and surrounded by low hills of sand on whose slopes the clay thins out. The clay has been excavated to a depth of 10 feet but is claimed to be at least 40 feet deep. It is a tough bluish clay (Lab. No. 1014) with yellow mottlings having the following physical characters: Color moist, light brown; soluble salts, .44; water required, 28.6; slaking, fast; plasticity, high; grit, little; air shrinkage, 7.6; average tensile strength 166 pounds per square inch with a maximum of 231 pounds per square inch. The material will not stand rapid drying and the large bricks tested in this manner split badly. The behavior of the clay in burning was as follows:

Wet-molded bricklets:				
Cone	010	05	03	1
Fire shrinkage	1.7	2.3	2.8	13.6
Color	light red	cream	light buff	yellow buff
Absorption	25.74	25.58	23.79	3.65

The clay burned steel hard at 03 and gave a good body even at 010. Its shrinkage up to 03 was quite low but above that increased rapidly as its fusion point was approached.

Dry-press bricklets:		
Cone	05	1
Fire shrinkage	2	12
Color	light buff	buff
Absorption	32.43	12.48

It gives a fairly good dry-press body at 05.

Uses. At the present time the clay is used by the Fort Atkinson Brick Mfg. Co. for the manufacture of common brick. For making these 7 parts of the clay are mixed with one of sand the latter being obtained from a neighboring hill. The molding is done in soft-mud horse-power machine, drying on pallets and burning in scove kilns.

Granville, Milwaukee Co. The estuarine clays have been dug about one half mile northwest of Granville station, for drain tile and brick purposes, and the deposit which has not been worked to a depth of more than 6 feet consists of alternate layers of a blue and red clay which it is said extends to a depth of about 9 feet, under which there is a solid blue clay which a well has penetrated to a depth of 200 feet. Both the surface clay and the underlying clay burn buff, and there seems to have been no leaching of the lime from the upper beds at this locality. As it was claimed that the surface 2 feet had a different character from the run of the bank including the lower bed a physical test was made of each with the following results:

Material	Surface clay	Run of bank
Lab. No	1112	1125
Color	brown	light brown
Soluble salts	.13	.19
Water required	25.3	22
Slaking	fast	slow
Plasticity	high	excellent
Grit	none	some, fine
Air shrinkage	9.5	7
Wet-molded bricklets—		
Cone 010;		
Fire shrinkage	.3	sl. sw.
Color	brownish yellow	buff
Absorption	17.86	27
Cone 05:		
Fire shrinkage	sl. sw.	.4
Color	brownish buff	cream
Absorption	17.99	26.78
Cone 03:		
Fire shrinkage	1	1
Color	brownish buff	cream
Absorption	13.26	25.93
Cone 1:		
Fire shrinkage	vis. beg.	1.4
Color	....	light buff
Absorption	....	24.58

The difference in character is here quite noticeable on comparing the air shrinkage, fire shrinkage, density and fusion points.

Of these two clays the surface one is a more easily fusible clay and became viscous at cone 1 while the other did not become viscous until two or three cones higher. The latter, however, burned to a fairly hard brick even at cone 010 and makes a good drain-tile.

Uses. At the present time the material is used chiefly for the manufacture of drain tile which are burned in up-draft kilns giving a good product at a comparatively low temperature namely 010.

A similar clay deposit has also been opened up by the Wisconsin Brick and Tile Company in eastern Granville, whose works are located on the east side of the Chicago and Northwestern track one mile north of Granville. There again the clay is cream burning although red in color and it is likewise somewhat stony in its character in places.

Milwaukee, Milwaukee Co. This city is the most important brick-making center in the state of Wisconsin, there being a number of large yards in operation for the manufacture of common and pressed brick. The clays worked around Milwaukee are to be classed geologically in part as lake clays, and in part as glacial deposits. Physically, they are to be classed as silty clays, but may show more or less variation in the same bank. All are of good plasticity. In some banks the laminations are quite distinct while in other banks the clay appears to be quite massive and the bedding planes are not at all prominent. Here and there through nearly all of the deposits are masses of bouldery clay or lenses of sand which in the working of the bank must either be thrown out or worked around. At most of the banks there is also a variable overburden of glacial drift which has to be stripped off before the clay can be dug. While the run of the Milwaukee clays is cream-burning, there is here and there a surface deposit of red-burning loamy clay which is dug to some extent by the local potters for the manufacture of common red earthenware. These deposits are always shallow and rarely of great extent. At the present time most of the clay used by the earthenware potters is obtained from the region around Bay View.

The following tests will serve well as indicating the physical character of the cream-burning Milwaukee clays.

Locality	Chase Brick Co.	Burnham Bros. Wauwatosa yard.
Laboratory number	1,080	1,009
Color, moist	gray	gray
Soluble salts	.17	.18
Water required	15.4	15.4
Slaking	fast	moderately fast
Plasticity	good	much, coarse
Air shrinkage	3.5	3.5
Average tensile strength	215	197
Maximum tensile strength	251	236
Wet-molded bricklets—		
Cone 010:		
Fire shrinkage	0	0
Color	gray buff	light pink buff
Absorption	23.43	20.33
Cone 05:		
Fire shrinkage	sl. sw.	0
Color	cream	light buff
Absorption	22.27	20.43
Cone 03:		
Fire shrinkage	sl. sw	sl. sw.
Color	cream	buff
Absorption	24	18.85
Cone 1:		
Fire shrinkage	sl. sw.	1.7
Color	light buff	buff
Absorption	20.70	10.37
Steel hard at cone 3	....	
Dry-press bricklets—		
Cone 3:		
Fire shrinkage	....	1.7
Color	....	buff
Absorption	....	10.15

Chemical composition.

Laboratory number	1,080
Silica (SiO_2)	37.76
Alumina (Al_2O_3)	9.07
Ferric oxide (Fe_2O_3)	3.60
Lime (CaO)	22.48
Magnesia (MgO)	2.84
Potash (K_2O)	2.07
Soda (Na_2O)	.54
Titanic acid (TiO_2)	.38
Loss on ignition	21.52
Total	100.26
Total fluxes	31.53

Uses. The clays around Milwaukee are used chiefly for the manufacture of common building brick but in addition some dry-press brick are also manufactured. The firms now in operation are the Chase Brick Co., The Standard Brick Co., Burnham Bros., M. Davelaar & Sons, and the Chas. Kraatz Brick Co. The methods of manufacture followed are summarized below.

Name.	Tempering.	Molding.	Drying.	Burning.
Standard Brick Co ...	Pug mills..	Dry-press and stiff mud.	Hot air tunnels.	Scove and continuous kiln.
Burnham Bros., Howell Ave. Yd.	....	Boyd dry press.	Tunnels ...	Continuous kilns.
Davelaar & Sons	Potts crusher.	Soft mud..	Pallets	Scove kilns
Chase Brick Co	Pug mill and corrugated rolls	Stiff mud, soft mud, dry press.	Steam heated tunnels.	Scove kilns
Kraatz Brick Co......	Ring pits..	Soft mud..	Open yard.	Scove kilns
Burnham Bros., Wauwatosa.	Pug mill ..	Stiff mud, dry press.	Hot air and steam tunnels.	Scove and continuous kilns.

Merrimack, Sauk Co. Bordering the Wisconsin river at this point there is a considerable deposit of clay and sand, which Buckley has classed as estuarine but which may be of glacial origin. It is of somewhat variable character consisting of large masses or lenses of clay surrounded by coarse stratified sands and sandy clay and even the most plastic portions of the clay are quite silty. Although there are two yards here, one on each side of the river, the largest excavation is that of the Merrimack Brick Co. on the southeast side of the river near the end of the railroad bridge. The bank here shows a very irregular deposit of clay surrounded by coarse to medium grained stratified sands and gravels. The clay itself varies from a laminated sandy clay to a tough silty clay, the latter being quite similar to some of the deposits worked around Milwaukee.

The part of the deposit exposed does not represent the thickest part as Mr. J. W. Brownrig states that a well bored at the engine house penetrated 90 feet of blue clay. For brick making the tough silty clay is not used alone but mixed with about 15 to 20 per cent of sand, the effect of this admixture being brought out by the following tests:

Material	Clay alone.	Brick mixture.
Lab. No	1162	1171
Soluble salts	....	.34
Color.	brown	brown
Water required	22	24.2
Slaking	fast	moderately fast.
Plasticity	good	good
Grit	some, coarse	sandy
Air shrinkage	6.5	4.5
Average tensile strength	....	181.4
Maximum tensile strength	....	219
Wet-molded bricklets—		
Cone 010:		
Fire shrinkage	.3	.3
Color	pink buff	light brown
Absorption	27.50	20.16
Cone 05:		
Fire shrinkage	sl. sw.	0
Color	light buff	cream
Absorption	28.33	20.73
Cone 03:		
Fire shrinkage	0	0
Color..	light buff	buff
Absorption	27.30	19.39
Cone 1:		
Fire shrinkage	0	3
Color..	light buff	buff
Absorption	26.50	13.40
Cone 3:		
Fire shrinkage	3	....
Color..	greenish buff	....
Absorption	16.24	....
Dry-press bricklets—		
Cone 05:		
Fire shrinkage	....	0
Color..	....	light buff
Absorption	....	24.30
Cone 1:		
Fire shrinkage	....	0
Color	....	light buff
Absorption	....	20.82

The brick mixture cracked very little in fast drying. The clay alone became steel hard at cone 1 but the brick mixture did not become steel hard until above this cone. It shows a lower air shrinkage and burns to a denser body, but shows little difference from the other in its fire shrinkage.

Uses. At the present time this clay is being used by the Merrimack Brick Co. for the manufacture of common brick. For this purpose it is put through a pair of rolls and then a soft-mud machine. The bricks are dried on pallets and burned in scove kilns. In order to get a hard brick it is necessary to burn the clay up to cone 3.

Portage, Columbia Co. The calcareous estuarine clays are well developed along the line of the Wisconsin Central railroad north of Portage and borings which have been made in several localities show that these clays are frequently from 40 to 50 feet deep. Only one test of this series of deposits was made, however, and that was taken from the point about 5 miles north of Portage along the line of Wisconsin Central railroad. This (Lab. No. 1121) is a porous clay of light brown color containing .33 soluble salts. It slaked moderately fast and worked up with 19.8 per cent of water to a mass of high plasticity and considerable grit. The air shrinkage was 4.6 per cent and the average tensile strength 189 pounds per square inch with a maximum of 227 pounds per square inch. In burning it behaved as follows:

Wet-molded bricklets—					
Cone	**010**	**05**	**03**	**1**	**2**
Fire shrinkage	**sl. sw.**	**sl. sw.**	**0**	**2.7**	**4.3**
Color	**cream**	**cream**	**cream**	**cream**	**deep buff**
Absorption	**25.33**	**23.84**	**18.72**	**16.46**	**13.07**

Dry-press bricklets—		
Cone	**05**	**1**
Fire shrinkage	**0**	**2.**
Color	**buff**	**light buff**
Absorption	**31.13**	**24.41**

The clay burns steel hard at cone 1, and its absorption is rather low for a calcareous clay.

The clay burns to a very clear color and gives a good brick body even at cone 010, while at 05 it gives a fairly good dry-press body. It is not being worked at the present time.

Portage, Columbia Co. Cream-burning clays are worked at several points around Portage City, one opening being at Sanborn's yard one mile south of the city and the other at H. C. Affeldt's about a mile west of the city. At Sanborn's yard

(Pl. VIII, Fig. 2) the clay is at least 30 to 40 feet deep and rather silty in its character with scattered pebbles of limestone and the run of the bank can be used for making brick. The section involves:

Sand	3 ft.
Ferruginous clay	1 ft.
Blue clay	16 ft.

At Affeldt's yard the section shows:

Loam	1 ft.
Red clay	6 to 12 in.
Sand clay	3 ft.
Hard clay	6 ft.

The sandy clay is said to be best, while the hard clay is dense and broken here and there by joint planes. If taken at once from the bank to the mixing machine it breaks up very slowly, but a few days of exposure would cause it to slake quite rapidly. The properties of the sandy clay and brick mixture at Affeldt's yard are as follows:

Material	Sandy clay	Brick mixture
Lab. No	1108	1113
Color	light brown	brick
Soluble salts	.24	.18
Water required	19.8	15.4
Slaking	slow	fast
Plasticity	fair	fair
Grit	much	much, fine
Air shrinkage	7.3	3.7
Wet-molded bricklets—		
Cone 010:		
Fire shrinkage	0	sl. sw.
Color	buff	light drab
Absorption	25.10	20.89
Cone 05:		
Fire shrinkage	sl. sw.	sl. sw.
Color	cream	light gray
Absorption	27.45	23.34
Cone 03:		
Fire shrinkage		sl. sw.
Color		light buff
Absorption		23.33
Cone 1:		
Fire shrinkage	sl. sw.	1
Color	cream	buff
Absorption	25.29	19.55
Cone 3:		
Fire shrinkage		1.3
Color		buff
Absorption		18.10

The first clay is very gritty and contains scattered mica scales, but burns to a cream brick of rather high absorption while the mixture, although somewhat sandy and of lower air shrinkage burns to a much denser product. In making the bricks it is necessary to fire the kiln up to cone 3.

Uses. The clays at both yards are used for the manufacture of common brick. At Affeldt's yard the clay is mixed in a pug mill and bricks molded by hand. They are dried on the yard and burned in scove kilns. The low shrinkage is well shown by the fact that in a kiln of 36 courses burned to cone 3 there is only 4 inches settle.

Horicon, Dodge Co. Both red and cream-burning estuarine clays are worked at this locality in the clay pit of J. W. Pluck about a half mile from Horicon. When fresh the red-burning clay is yellow and the cream-burning clay is blue and although the two are taken from separate pits the former probably overlies the latter so that the section would involve:

Black loam	6 in.
Red clay	2½ ft.
Blue clay	exact thickness unknown.

The properties of the blue cream-burning and the red-burning brick mixture are given below.

Material	Blue clay	Red clay, brick mixture
Lab. No.	1057	1058
Water required	15.4	22
Plasticity	fair	excellent
Grit	much, silty	some, coarse
Air shrinkage	1.6	6.1
Wet-molded bricklets—		
Cone 010:		
Fire shrinkage	sl. sw.	sl. sw.
Color	gray	light red
Absorption	32.84	17.49
Cone 05:		
Fire shrinkage	sl. sw.	0
Color	pink buff	red brown
Absorption	36.53	16.40
Cone 03:		
Fire shrinkage	sl. sw.	.3
Color	cream	red brown
Absorption	37.13	14.21
Cone 1:		
Fire shrinkage	sl. sw.	8.4
Color	buff	dark red brown
Absorption	38.51	1.36

These two layers certainly show the strongest contrast. The former (Lab. No. 1057), is porous and sandy when air dried, while the mixture gives a good hard body when air dried. The former has practically no shrinkage, burns to a porous body and is not steel hard until cone 1, while the latter becomes steel hard at 05, shows a much higher fire shrinkage and greater density, fusing about cone 3, the sudden jump in the fire shrinkage at cone 1 being an indication that the fusion point is approaching.

Uses. At the present time a mixture of the clays and the sand in equal proportions is used for making a common brick. The clay is treated in a soak pit, and molded by hand, while the drying is done on the yard and the burning in scove kilns.

Kewaskum, Washington Co. The cream-burning clays have been opened on the property of H. F. Buss 1½ miles west of Kewaskum. The clay is known to underlie at least 15 acres and is claimed to have a depth of at least 5 feet. It has a yellowish-red color and shows a varying amount of sand, but the excavations which have been made at the brick works are quite shallow.

A second deposit of clay located in the northern part of the village is being worked by William F. Miller, where the property has been tested over an area of three acres and the clay showed a similar depth to that at the other yard. The stripping at both places is very small and ranges from a foot to 18 inches. The properties of the two clays are given below.

Locality	H. F. Buss.	W. F. Milles
Material	....	brick mixture.
Laboratory No	1,160	1,161
Color	brown	brown
Water required	22	18.7
Slaking	slow	moderately fast
Plasticity	high	high
Grit	fine	very low
Air shrinkage	5.5	5.5
Wet-molded bricklets—		
Cone 010:		
Fire shrinkage	0	.4
Color	cream	pink
Absorption	34.49	25.71
Cone 05:		
Fire shrinkage	sl. sw.	sl. sw.
Color	cream	cream
Absorption	37.20	24.41
Cone 03:		
Fire shrinkage	sl. sw.	sl. sw.
Color	cream	cream
Absorption	36.90	24.61
Cone 1:		
Fire shrinkage	sl. sw.	2
Color	cream	buff
Absorption	35.92	22.11
Cone 3:		
Fire shrinkage	3.7	2.3
Color	buff	greenish buff
Absorption	22.74	17.02

Both of these clays are good buff-burning brick clays but that from Miller's yard burns to a denser body than that from Buss' yard.

Schleisingerville, Washington Co. A few hundred feet northwest of the railroad station of the Wisconsin Central R. R. the clay has been opened by P. W. Kortemeyer. The section there shows:

Loam	4 ft.
Yellow clay	6 ft.
Blue clay	14 ft.

The yellow clay burns red, while the blue clay burns white, but a mixture of the two in the proportion of one of the former to two of the latter gives a cream-colored brick, the addition of sand being unnecessary. The properties of the top loam, blue clay and the yellow clay are as follows:

Material	Top loam	Blue clay.	Yellow clay.
Laboratory No.	1,054	1,053	1,055
Water required	22	19.8	29.2
Plasticity	high	good	very good
Grit	little	little	little
Air shrinkage	5	4.6	5.4
Wet-molded bricklets—			
Cone 010:			
Fire shrinkage	0	.7	.4
Color	pale red	pink buff	pink
Absorption	19.11	23.53	25.99
Cone 05:			
Fire shrinkage	0	.6	.3
Color	light red	cream	cream
Absorption	19.15	22.98	25.54
Cone 03:			
Fire shrinkage	1	1	.3
Color	red brown	cream	buff
Absorption	14.75	21.90	24.58
Cone 1:			
Fire shrinkage	5.4	10.3	7
Color	gray brown	yellow buff	yellow buff
Absorption	1.69	1.40	7.10
Cone 2:			
Fire shrinkage	....	....	7.6
Color	....	....	brown'hbuff
Absorption	....	....	2.04
Cone 4:			
Fire shrinkage	....	....	8.6
Color	....	....	greenish yel.
Absorption	....	....	.324
Cone 5:			
Fire shrinkage	....	....	viscous

A comparison of the physical properties of these three layers is not without interest. Here we have three clays, quite different in appearance and somewhat different in feel, and yet resembling each other somewhat closely up to a certain point. Thus their air shrinkages are close, and the fire shrinkages similar up to cone 03, but above this they separate considerably, the more easily fusible blue clay showing a sudden increase in shrinkage at cone 1. There is also a marked increase in density of all three at this cone, but the top loam burns denser from the start.

Uses. These three clays are used for the manufacture of common brick but much trouble is experienced with water in digging the material. The brick are made on a soft-mud horsepower machine, dried on the yard, and burned in a scove kiln.

A second yard is operated at this locality by Mr. Rosenheim and the clay here is in all respects similar to that at Kortemeyer's yard.

Port Washington, Ozaukee Co. The lake clays outcrop in the high banks along the lake front, and show a variable section from point to point, but all the sections agree essentially in exhibiting thick deposits of laminated siliceous clays which in places are overlain by glacial drift. The clays are being worked at two points, the most northerly one being at Gunther Bros.' yard, while a short distance further south they are digging clay for the yard of J. Schramke. At Gunther Bros.' yard which is located on the northeast edge of town along the lake shore the section shows about 25 feet of laminated interbedded silty and plastic clays covered by 6 to 15 feet of glacial drift. In mining however it is possible to separate the more plastic beds from the run of the bank so that the former can be used for drain tile, while the latter is employed for common brick manufacture. The characters of the run of the bank (Lab. No. 1143) are as follows: Color, brown; soluble salts, .20; water required, 22; slacking, slowly; plasticity, high; grit, much, silty; air shrinkage, 7 per cent; average tensile strength 283.2 pounds per square inch with a maximum of 334 pounds per square inch.

In burning the clay behaved as follows:

Wet-molded bricklets:						
Cone	010	05	03	1	3	4
Fire shrinkage	.6	0	1	1 6	7.6	viscous
Color	pink buff	buff	buff	deep buff	greenish	....
Absorption	20	19.78	17.65	14.46	....	....

The clay does not burn steel hard until cone 3, and although quite gritty yields a good buff body.

Uses. The run of the bank is used for making common brick, the clay being molded in a stiff-mud machine, dried on pallets, and burned in scove kilns. The tiles are also molded on a stiff-mud machine and burned in Dutch kilns.

At Schramke's yard the clay is similar to that of Gunther's but the bank is higher and the over burden of gravel is very much thicker. The clay here is molded in a soft-mud machine or in a dry-press machine. If that used for the latter was ground finer before being pressed it would give a much better product.

The clays at both banks are highly calcareous and the analysis of Gunther's clay is given below:

Silica (SiO_2)	42.50
Alumina (Al_2O_3)	9.58
Ferric oxide (Fe_2O_3)	4.11
Lime (CaO)	14.52
Magnesia (MgO)	5.33
Potash (K_2O)	2.59
Soda (Na_2O)	1.04
Titanic acid (TiO_2)	.07
Loss on ignition	19.49
Total	99.25
Total fluxes	27.59

Endeavor, Marquette Co. The calcareous clays worked here are like those occurring further south between Endeavor and Portage, the tests of which have been described on an earlier page. A sample of the run of the bank (Lab. No. 1019) showed that the clay worked up with 27 per cent of water to a mass of good plasticity and containing some coarse grit, and having an air shrinkage of 6.04 per cent. In burning it behaved as follows:

Wet-molded bricklets:					
Cone	010	05	03	1	2
Fire shrinkage	0	0	2.8	9	viscous
Color	cream	cream	buff	buff	....
Absorption	25.44	25.22	19.93	.30	....

The clay burns steel hard at cone 1 and for brick should not be burned at a lower temperature than 010.

Uses. The clay has been used for bricks by the students of the Academy at Endeavor. If properly burned it would make a very good product.

Oakfield, Fond du Lac Co. This is one of the two localities at which the Cincinnati shale has been utilized, and even there the yard is not in operation at the present time, although the deposit has not given out. At this point the shale has been more or less weathered in its upper portion and makes a fairly plastic clay. Here and there in the beds there are harder layers of somewhat concretionary character which have not weathered and are left as stony lumps within the clay mass. Nevertheless the clay (Lab. No. 1018) as a whole is quite fine grained and free from grit. When tested physically it was found to contain .09 of soluble salts, and slaked slowly to a mass of good plasticity and no grit. It worked up with 18.7 per cent of water to a mass whose air shrinkage was 4.4 per cent and whose average tensile strength was 105 pounds per square inch with a maximum of 132 pounds per square inch. In burning it behaved as follows:

Wet-molded bricklets:						
Cone	010	05	03	1	3	4
Fire shrinkage	0	sl. sw.	sl. sw.	sl. sw.	sl. sw.	3.6
Color	deep buff	deep buff	buff	pink buff	brownish buff	buff
Absorption	30	29.73	25.92	22.15	28.79	25.65

The clay works very well for the manufacture of buff brick or even drain tile, but it will not stand rapid drying without cracking somewhat. On account of the proximity of this deposit to several large towns, there is no apparent reason why the product made from this clay should not find a good market.

Sheboygan, Sheboygan Co. The lake clay outcrops in considerable abundance at this locality there being several exposures along the banks of the Creek, which are all worked for the manufacture of common brick, but the sections at the different yards vary slightly. In general it consists of a variable but usually thin layer of sandy stripping underlying which there is usually from 6 to 15 feet of reddish clay representing the weathered part of the deposit and this in turn rests on blue clay which extends down to the limestone below. The clays which in general are cream-burning, silty, and have to be burned at from cone 1 to 3 in order to produce a product of sufficient hardness. They have the following properties:

Firm	O. Zimbal Br'k Co.	F. Zurheide
Material	run of bank	run of bank
Lab. No	1148	1150
Color, moist	brown	brown
Soluble salts	.29	
Water required	22	17.6
Slaking	slow	slow
Plasticity	good	high
Grit	little	some, coarse
Air shrinkage	7.1	5.3
Wet-molded bricklets —		
Cone 010:		
Fire shrinkage	.3	sl. sw.
Color	light pink buff	pink buff
Absorption	26.70	22.85
Cone 05:		
Fire shrinkage	sl. sw.	0
Color	buff	buff
Absorption	25.22	22.53
Cone 03:		
Fire shrinkage	sl. sw.	.6
Color	cream	buff
Absorption	24.20	20.23
Cone 1:		
Fire shrinkage	2.6	
Color	buff	
Absorption	19.71	
Cone 3:		
Fire shrinkage	....	3.7
Color	....	buff
Absorption	....	14.81
Cone 5:		
Fire shrinkage	....	viscous
Dry-press bricklets —		
Cone 1:		
Fire shrinkage	2	
Color	cream	
Absorption	31.90	

The chemical composition of Zimbal's clay is:

Silica (SiO_2)	36.95
Alumina (Al_2O_3)	6.70
Ferric oxide (Fe_2O_3)	3.60
Lime (CaO)	20.55
Magnesia (MgO)	8.95
Potash (K_2O)	1.31
Soda (Na_2O)	1.13
Titanic acid (TiO_2)	.12
Loss on ignition	21.22
Total	100.53
Total fluxes	35.54

The clays do not burn steel hard until cone 1.

Uses. The clays at this locality are used almost exclusively for the manufacture of common brick by three firms namely: Frederick Zurheide, O. Zimbal Brick Co., and the Sheboygan Brick & Tile Co. At all three yards the clay is molded by the stiff-mud process, dried on hacks on the open yard and burned in scove kilns. A variable quantity of sand is added to the clay in order to prevent excessive shrinking and cracking in drying and burning.

In the top of Zimbal's bank there is a thin layer of red clay, of easily fusible character which is referred to under slip clays.

Plymouth, Sheboygan Co. One mile east of the Chicago & Northwestern station a deposit of red and blue cream-burning clay has been opened up for the manufacture of common brick. The clay contains scattered pebbles as well as limonite spots. It (Lab. No. 1159) works up with 22 per cent of water to a mass of high plasticity containing little fine grit. Its air shrinkage is 7.1 per cent. In burning it behaved as follows:

Wet-molded bricklets:					
Cone	010	05	03	1	5
Fire shrinkage	.4	0	1	1.7	thoroughly viscous
Color	cream	cream	cream	buff	....
Absorption	28.80	28.63	27.58	25.33	....

This clay is similar in its general characters to the run of cream-burning brick clays. It does not become steel hard until cone 1 and viscosity begins at cone 3.

Uses. At the present time it is employed chiefly for common brick, being soaked in a pit, and molded on a stiff-mud side-cut machine. The clay is naturally quite tough and unless thoroughly mixed is apt to remain lumpy and thereby injure the strength of the brick. Some tile have been made from it.

Elkhart, Sheboygan Co. The clays at this locality have been worked off and on for the manufacture of common brick and the section involves an upper red-burning clay and a lower cream-burning clay, both of which contain more or less pebbles scattered through them. The two clays have never been used separately but the run of the bank has been employed, the result being the production of a streaked brick.

Neenah-Menasha, Winnebago Co. The clay deposits in this vicinity have been opened up at W. H. Carter's Brick Yard in whose clay bank the section is:

Sandy yellow, stratified clay	4 ft.
Chocolate red clay	8 ft.
Blue clay	depth unknown.

The physical properties of the run of the bank (Lab. No. 1045) were soluble salts, .18; water required, 28.6; slaking, moderately fast; plasticity, high; grit, little; air shrinkage, 7.7 per cent; average tensile strength 202 pounds per square inch with a maximum of 246 pounds per square inch. In burning it behaved as follows:

Wet-molded bricklets:					
Cone	010	05	03	1	2
Fire shrinkage	.4	1.7	1.7	9.7	viscous
Color	cream	cream	cream	buff	....
Absorption	22.77	21.17	20.09	.06	....

The clay burns steel hard at 05.

Dry-press bricklets:		
Cone	05	1-2
Fire shrinkage	1.33	viscous
Color	light buff	....
Absorption	28.19	....

This clay burns steel hard at a lower temperature than most of the cream-burning clays and gives a good brick even at cone 010. Up to the point of vitrification the shrinkage is very low and then increases suddenly.

Uses. The clay is employed for the manufacture of common brick which are molded on a stiff-mud machine. For their manufacture the section of the deposit is worked down to the top of the blue clay, the top and the middle beds being used in the proportion of 1 to 2.

Stockbridge, Calumet Co. Here again the Cincinnati shale is worked. The clay outcrops as a bank some 60 feet high on the east side of Lake Winnebago, showing a section of:

Yellow clay	4 ft.
Yellow shale	56 ft.

On exposure to the weather the shale slakes down quite rapidly, but the properties of the upper yellow clay and the underlying shale are somewhat different, the former having a higher air shrinkage, but burning to a denser body, and being somewhat more fusible.

Material	Upper clay	Lower shale
Lab. No.	1167	1168
Water required	20.9	13.2
Slaking	slow	slow
Plasticity	high	good
Grit	very fine	not much
Air shrinkage	5.1	3
Wet-molded bricklets—		
Cone 010;		
Fire shrinkage	0	.4
Color	pink buff	gray buff
Absorption	21.80	20.19
Cone 05:		
Fire shrinkage	sl. sw.	0
Color	brownish buff	gray buff
Absorption	21.74	22.11
Cone 03:		
Fire shrinkage	sl. sw.	sl. sw.
Color	brownish buff	gray buff
Absorption	18.14	13.76
Cone 1:		
Fire shrinkage	sl. sw.	sl. sw.
Color	brownish buff	gray buff
Absorption	14.76	26.11
Cone 5:		
Fire shrinkage	viscous	....

The clay burns steel hard at 03.

Of the two clays the shale is naturally the harder, and gives a more granular brick than the top clay.

Uses. The materials are at present used for the manufacture of common brick and the mixture of 1-3 of the top clay and 2-3 of the shale are taken the latter being allowed to weather somewhat before it is molded. The clay is prepared in a dry pan and molded on a soft-mud machine. Burning is done in scove kilns. Some tile are also manufactured and these are burned in a down-draft kiln. The clay would probably work for dry-press brick but none have been made for some time. It is noticed in burning that the clay becomes viscous before shrinking to any extent in the fire. There is no limestone overlying the shale at the bank, but a few hundred feet back from the bluff it outcrops prominently.

Eastwin, Manitowoc Co. The lake clays are dug at a small yard operated by P. Schaf about three miles from Two Rivers and the clay is much like that at Bertle's yard at Manitowoc being red above and blue below. The section involves

Sand	1 to 2 ft.
Clay	8 ft.
Sand	7 ft.
Clay	50 ft.

The run of the bank is used and no care is taken to exclude the lime pebbles from it. The bricks burn to a cream color and settle 3 inches in 40 courses in scove kilns.

Manitowoc, Manitowoc Co. The lake clays are extensively worked around the city of Manitowoc but the best exposure of them is in the bank of the Manitowoc Clay Product Company, the section of which shows:

Loam and soil with sandstone pebbles	2 ft.
Red clay	6 ft.
Blue clay with sandy streaks	8 ft.
Fat blue clay	depth unknown.

Scattered through the deposit there are a few limestone boulders showing glacial scratches. This bank is worked over by falling but at other banks the clay is worked by simply digging or excavating with a plow.

The following tests will serve to illustrate very well the character of the clay in this vicinity.

Firm	Manitowoc Clay Prod. Co.	Manitowoc Clay Prod. Co.
Material	top clay	bottom clay
Lab. No	1153	1155
Color, moist	brown	brown
Soluble salts	...	.36
Water required	27	23
Slaking	...	slow
Plasticity	high	high
Grit	some, fine	
Air shrinkage	7.2	6.3
Average tensile strength	...	245
Maximum tensile strength	...	269
Wet-molded bricklets—		
Cone 010:		
Fire shrinkage	.7	.7
Color	pink buff	pink buff
Absorption	22.11	22.44
Cone 05:		
Fire shrinkage	1.3	1
Color	whitish	cream
Absorption	22.41	22.55
Cone 03:		
Fire shrinkage	1.3	2
Color	cream	bnff
Absorption	22.27	20.36
Cone 1:		
Fire shrinkage	...	5
Color	...	dark buff
Absorption	...	15.31
Cone 3:		
Fire shrinkage	5.3	8.3
Color	green buff	dark buff
Absorption	12.56	9.70

1153 is steel hard at cone 3, and 1155 at cone 1.

Chemical analysis.

Lab. No	1153	1155
Silica (SiO_2)	41.70	41.53
Alumina (Al_2O_3)	11.29	10.02
Ferric oxide (Fe_2O_3)	2.77	5.00
Lime (CaO)	15.40	14.33
Magnesia (MgO)	3.32	4.24
Potash (K_2O)	3.05	4.39
Soda (Na_2O)	1.27	.55
Titanic acid (TiO_2)	.38	.10
Loss on ignition	19.84	19.52
Total	99.02	99.68
Total fluxes	25.81	28.51

These tests show the bank to be of rather uniform character in both its physical and chemical properties, but neither layer could be used for making paving brick. Although the clays do not burn steel hard at a very low cone, still an excellent grade of brick is made by burning at cone 08–05.

Uses. The clays around Manitowoc are employed chiefly for the manufacture of common brick. At the smaller yards the method of manufacture is quite simple, involving soft-mud pressing, drying on pallets and burning in scove kilns.

At the larger plant the clays are passed through rolls and pug mills, molded on a soft-mud machine, dried in tunnels and burned in scove kilns. The temperature reached in burning is cone 08.

The following analysis of the blue clay at the yard of the Manitowoc Clay Prod. Co., was made by E. G. Smith of Beloit.

Silica (SiO_2)	39.04
Alumina (Al_2O_3)	13.60
Ferric oxide (Fe_2O_3)	3.44
Lime (CaO)	14.81
Magnesia (MgO)	7.33
Potash (K_2O)	2.55
Soda (Na_2O)	1.08
Carbonic acid (CO_2)	13.31
Water (H_2O)	5.56
Total	100.72
Total	29.21

This in general is not unlike the analysis made of the blue clay from a sample collected by the writer.

Milladore, Wood Co. A deposit of calcareous clay occurs at Milladore on the north side of the Wisconsin Central Railroad and on the property belonging to Mr. Wells. It is covered by from 4 to 6 feet of surface clay under which comes the calcareous clay whose depth is in places at least 33 feet. The occurrence of this is rather peculiar as it lies in the residual area and there are no other calcareous clays near it, the land having been examined from Milladore westward to Marshfield, and also in the other directions for some distance. The physical properties of this clay (Lab. No. 1119) determined from a sample collected by Mr. F. H. Merrell of Portage were: soluble salts, .44; water required, 22; slaking, slow; plasticity, high; grit, some, coarse; air shrinkage, 5.2 per cent; average tensile strength, 245 pounds per square inch with a maximum of 269 pounds per square inch.

In burning it behaved as follows:

Wet-molded bricklets:					
Cone	010	05	03	1	2
Fire shrinkage	.3	.7	1	7.6	viscous
Color	cream	cream	cream	buff	....
Absorption	18.94	18.31	14.76	2.44	....

The clay burns steel hard at cone 1.

Dry-press bricklets:	
Cone	05
Fire shrinkage	.66
Color	light buff
Absorption	23.60

The partial chemical analysis as given by A. S. Mitchell of Milwaukee was

Silica (SiO_2)	52.60
Alumina (Al_2O_3)	12.60
Ferric oxide (Fe_2O_3)	3.82
Lime (CaO)	12.77
Magnesia (MgO)	3.22
Loss on ignition	12.49
Total	97.50

The clay gives a good hard brick even at cone 010. Some of the lime is in lumps and unless ground up would cause trouble by splitting, even at a low cone. The clay burns to a very fair dry-press brick body even at cone 05.

New London, Waupaca Co. The estuarine clays underlie the flats around this town and have been opened up at the yard of Zerrener Bros. (Plate X, Fig. 1) where they show the following section:

Red-burning clay	2 ft.
White-burning clay	6 ft.
Clay	2 ft.
Very plastic pink buff clay	2 ft.
Very plastic pink clay	4 ft.
Black sand	

The clays are exposed in a pit about 10 feet deep and 75 feet long, and show the usual laminated structure characteristic of the estuarine deposits.

The physical properties of the red and cream-burning clays are given below.

Material	Red-burning clay	Cream-burning clay
Labratory No.	1,140	1,145
Color	brown	brown
Soluble salts	.21	.18
Water required	19.8	19.8
Slaking	fast	moderately fast
Plasticity	good	high
Grit	much, fine	some
Air-shrinkage	3.9	3.4
Average tensile strength	225	207
Maximum tensile strength	254	246
Wet-molded bricklets—		
Cone 010:		
Fire shrinkage	.7	sl. sw.
Color	pink buff	pink buff
Absorption	17.90	24.62
Cone 05:		
Fire shrinkage	0	sl. sw.
Color	brown buff	buff
Absorption	18 96	24.04
Cone 03:		
Fire shrinkage	1	.7
Color	brown buff	gray buff
Absorption	16.38	20.80
Cone 1:		
Fire shrinkage	vis. begun	5.3
Color	....	gray buff
Absorption	....	9.54
Cone 3:		
Fire shrinkage	....	10.3
Color	....	greenish
Cone 5:		
Fire shrinkage	....	viscous
Steel hard	03	1

There is not much difference in the fire shrinkage of the two clays, but the red-burning one on account of its lower percentage of lime, shows a lower absorption. It is however more fusible.

Uses. The clays are used at the present time for the manufacture of common brick, both red and cream brick being made.

The molding is done in a soft-mud machine, drying on pallets, and burning in scove kilns. It is probable that this clay would work dry-press although attempts in this direction have not been made.

A similar clay is worked at August Prahl's, 2 miles east of New London.

Kaukauna, Outagamie Co. The clay outcrops here in a bank about 30 feet high and consists of strongly laminated layers of red and brown clay but no underlying layer of sand is exposed now as there was at the time Dr. Buckley visited it, although under the bank at one place there was sandy blue clay. At the north end of the bank the clay is underlain by a very heavy bed of sand which in turn rests on a bed of light gravel. There is said to be a difference in shrinkage between the tough light red layer and the dark brown layer of the clay. The difference between the run of the bank and the green brick mixture is well shown in the following tests.

Material	Brick mixture	Run of bank
Lab. No	1074	1139
Water required	17.6	29.7
Slaking	slowly	slowly
Plasticity	some, coarse	....
Air shrinkage	7.3	9.39
Wet-molded bricklets:		
Cone 010:		
Fire shrinkage	0	sl. sw.
Color	pink	pink buff
Absorption	20.16	17.90
Cone 05:		
Fire shrinkage	.3	.6
Color	pink buff	light pink buff
Absorption	20.95	19.87
Cone 03:		
Fire shrinkage	.7	4.6
Color	light buff	brownish buff
Absorption	22.96	7.41
Cone 1:		
Fire shrinkage	1.3	....
Color	buff	....
Absorption	12.57	....
Cone 2:		
Fire shrinkage	5	....
Color	brownish buff	....
Absorption	5	....

Cone 3:		
Fire shrinkage	5.3	thoroughly viscous
Color	deep greenish buff	....
Absorption	4.11	....
Cone 5:		
Fire shrinkage	viscous	....
Burn steel hard at cone	05	.03

The clay itself is fine-grained, and laminated but burns to a fairly hard body even at cone 010 and would probably work for the manufacture of drain tile. The brick mixture owing to the addition of sand is very gritty and while it burns to a good hard bricklet has a much higher porosity. The sudden increase in fire shrinkage at cone 2 is quite noticeable.

Uses. Clay is worked at the yard of Lindauer & Rhodes for the manufacture of common brick. It is molded in a soft-mud machine, dried on pallet racks, covered by canvas, and burned in scove kilns. Many of the brick show occasional lime pebbles and limonite spots as well as cracks.

Green Bay, Brown Co. The condition of the industry around this city may be summarized in the following list of manufacturers, their location and product.

Christian Hansen, 2½ miles north east of Green Bay. Product, hand-molded common brick.

Roffers & Albers, south of Green Bay. Common soft-mud brick and drain tile, the former both red and cream color.

Barkhausen Brick Co., just south of town. Product both red and cream-colored brick either common or dry-press.

John Hockers, south of Green Bay on the east side of the river. Soft-mud common brick, the top clay burning red and the bottom clay white.

John van Laanen. Common soft-mud brick, red with white spots, the latter due to cream-burning clay in the mixture.

Duckcreek Brick Co., at Duck Creek near Green Bay, soft mud common brick both red and cream color.

Green Bay Brick Co., at Duck Creek near Green Bay, common soft-mud brick both red and cream color.

Chemical analyses.

Lab. No.	1046	1084
Silica (SiO_2)	43.58	44.92
Alumina (Al_2O_3)	11.99	12.71
Ferric oxide (Fe_2O_3)	4.63	5.40
Lime (CaO)	13.04	12.06
Magnesia (MgO)	4.20	4.91
Potash (K_2O)	3.17	3.08
Soda (Na_2O)	3.13	1.23
Titanic acid (TiO_2)	......	.09
Loss on ignition	16.74	15.84
Total	100.48	100.24
Total fluxes	28.17	26.68

PHYSICAL PRORERTIES OF 1046, 1084, 1175, 1089, 1106, 1066, 1067.

1046. A buff-burning clay which gives a good brick even at cone 010, although it should preferably be burned at 05. It becomes viscous slightly above cone 1.

1084. This is a cream burning clay which becomes viscous very little below cone 1 and will also work dry press.

1175. When wet-molded this burns all right up to cone 010 but above that tends to swell due probably to the presence of organic matter.

1089. For good results this clay should not be burned under 05. It has a low fire shrinkage up to cone 1 at which cone it becomes very much darker and the finer portions of the clay show signs of viscosity.

1106 is a very porous gritty clay which gives a good common brick body.

1066. This is a rather tough clay which has to be thoroughly pugged, burns to a good red color, but shows signs of fusion at a rather low cone, namely cone 1.

1067. This is a gritty greenish-buff clay which burns to buff at lower cones and then burns to greenish buff, this change taking place suddenly between 03 and 1.

The details of the physical tests are given below.

Locality	Green Bay	Green Bay	Green Bay	Green Bay.	Green Bay	Duck Creek.	Duck Creek
Firm	Roffers & Albers.	Barkhausen Brick Co.	Barkhausen Brick Co..	Hansen's Yard.	Hansen's Yard.	Duck Creek Brick Co.	Duck Creek Brick Co.
Material	blue clay	white-burning clay	red-burning clay	run of bank	red top clay	lower half of clay for red-burning brick	Green brick mixture.
Lab. No	1046	1084	1175	1089	1106	1066	1067
Soluble salts	.30	.27	.20	....	....	....	....
Water required	27.5	26.4	31.9	17.6	22	22	20.9
Slaking	....	....	....	....	fast	moderately fast	moderately fast
Plasticity	good	high	high	good	good	good	excellent
Grit	none	some, fine	none	much, coarse	some	some, coarse	very little
Air shrinkage	7.4	8	10.9	5.1	6.2	7.6	6.1
Average tensile strength	....	267.2	386	....	....	....	....
Maximum tensile strength	....	333	464	....	....	....	....
Wet-molded bricklets—							
Cone 010:							
Fire shrinkage	.3	.4	1.3	sl. sw.	sl. sw.	0	.3
Color	pink	light red brown	yellow brown	red brown	pink	light red	pink
Absorption	26.56	20.55	11.55	11.65	13.53	14.15	21.71
Cone 05:							
Fire shrinkage	.6	1	....	0	.4	3	0
Color	cream	pink buff	....	light red	light brown	red	cream
Absorption	25.81	20.22	....	10.80	13.96	10.40	21.10
Cone 03:							
Fire shrinkage	.6	1.4	....	1	....	6.7	1.6
Color	dark cream	cream	....	red brown	....	brown red	cream
Absorption	23.22	15.74	....	7.28	....	7.27	23.38

Cone 1:							
Fire shrinkage	11.4	8.7	....	5	....	6	7.7
Color	buff	greenish buff	....	dark red brown	....	red brown	greenish buff
Absorption	.10	0	....	1.94	....	.98	.69
Cone 2:							
Fire shrinkage	....	....	....	....	....	....	10
Color	....	....	....	....	....	....	greenish yellow.
Absorption	....	....	....	....	....	....	.05
Cone 5:							
Fire shrinkage	....	....	....	....	....	....	viscous
Steel hard at cone	03	1	....	03	....	05	1

Algoma, Kewaunee Co. Brick clays have been dug at the yard of F. Storm near this town. The section of the bank shows:

Yellow-red clay	4 ft.
Tough red clay	2 ft.
Light yellow clay	18 in.
Blue clay	8 ft.

For making bricks a mixture of 1-2 of the red top clay with 1-2 of the white-burning or blue clay is taken. This clay is not laminated in its character but very tough and contains occasional pebbles. The bricks are made in a soft-mud machine and burned in scove kilns. They burn to a cream color. No tests were made of it.

Kewaunee, Kewaunee Co. There are several yards at this locality, whose clay banks show similar characteristics. The clays are all rather thinly laminated and overlain usually by very little glacial drift or sand. There is commonly a yellow top clay with an average depth of five feet which is red-burning, but quite full of pebbles, while underlying it is usually a bottom blue clay that is used to a depth of 5 to 8 feet, but whose observed maximum thickness as determined by a well boring is said to be at least 40 feet thick. This blue clay is said to rest on a bed of gravel. Two samples were tested from this locality, one from Borgman's yard (Lab. No. 1068) and the other from the yard of Kierweg & Heck (Lab. No. 1078). Their physical properties were as follows:

	Borgman.	Kierweg & Heck
Lab. No.	1068	1078
Soluble salts	.18	.19
Water required	17.6	24.2
Slaking	fast	fast
Plasticity	excellent	good
Grit	some, coarse	little, fine
Air shrinkage	5.7	8.5
Average tensile strength	299.6	
Maximum tensile strength	336	
Wet-molded bricklets—		
Cone 010:		
Fire shrinkage	0	.7
Color	pink	pink buff
Absorption	21.73	42.58

Cone 05:		
Fire shrinkage	0	.3
Color	cream	cream
Absorption	22.58	23.42
Cone 03:		
Fire shrinkage	0	.3
Color	cream	cream
Absorption	19.45	23.47
Cone 1:		
Fire shrinkage	2.4	5.5
Color	buff	buff
Absorption	17.61	15.29
Cone 2:		
Fire shrinkage	4.3	
Color	buff	
Absorption	10.44	
Cone 3:		
Fire shrinkage	5	
Color	greenish buff	
Absorption	8.30	
Cone 5:		
Fire shrinkage	nearly viscous	
Steel hard at cone	1	

1068. This clay burns to a good cream body of somewhat lower absorption than most of the calcareous clays used.

1078. This absorbs more water, has a higher air shrinkage, as well as fire shrinkage. It also shows a higher absorption when burned.

Both of these clays are used for the manufacture of common soft-mud brick.

Shawano, Shawano Co. The clays at this locality have been worked by Charles Larsen for some time. The deposits underlie about 20 acres and the total depth of the clay, which is thinly laminated throughout is not exactly known.

The section of the pit can be differentiated into an upper red clay and a lower blue clay, and the bricks are made from a mixture of the two, including top sandy clay. The properties of the two clays and the brick mixture are given below.

Material	Brickmixture	Upper red clay	Lower blue clay
Laboratory No	1,164	1,165	1,166
Water required	18.7	25.3	22
Slaking	fast	slow	slow
Plasticity	high	high	high
Grit	much, fine	little	none
Air shrinkage	5	8.2	7.3
Average tensile strength	290.2		
Maximum tensile strength	362		
Wet-molded bricklets—			
Cone 010:			
Fire shrinkage	sl. sw.	.3	sl. sw.
Color	pink buff	pink	cream
Absorption	19	24.44	25.28
Cone 05:			
Fire shrinkage	sl. sw.	0	0
Color	pink cream	light buff	cream
Absorption	20.76	25.31	27.14
Cone 03:			
Fire shrinkage	3.4	.3	sl. sw.
Color	buff	buff	cream
Absorption	10.88	23.50	25.87
Cone 1:			
Fire shrinkage	6	6.7	6.6
Color	green. buff	green. buff	green. buff
Absorption	.60	6.53	8.18
Cone 3:			
Fire shrinkage	vis.	vis	12.7
Color			green. buff
Absorption			0
Cone 4:			
Fire shrinkage			viscous
Steel hard at cone	03		1
Dry-press bricklets—			
Cone 1:			
Fire shrinkage	6.66		
Color	gray buff		
Absorption	16.70		

These tests show in an interesting way, the manner in which a mixture produces desirable results giving reduced water absorption and air shrinkage as well as greater density in the product.

The chemical composition of the brick mixture is:

Silica (SiO_2)	59.56
Alumina (Al_2O_3)	10.19
Ferric oxide (Fe_2O_3)	4.68
Lime (CaO)	8.28
Magnesia (MgO)	2.64
Potash (K_2O)	2.58
Soda (Na_2O)	.80
Titanic acid (TiO_2)	.07
Loss on ignition	11.14
Total	99.94
Total fluxes	18.98

Uses. The clay is used for the manufacture of soft-mud common brick.

Surings, Oconto Co. There are two yards here, one operated by S. Nelson, and the other by C. Heise. The clays which are both red and cream-burning are known to have a thickness of at least 20 feet.

At Heise's yard there is a foot and a half of red-burning clay on the top of the bank while the rest is cream-burning, and the beds are sometimes separated for use, while at Nelson's yard there is an upper red-burning and lower cream-burning bed. The properties of the clays are given below.

Locality	Heise's yd.	Heise's yd.	Nels'n's yd.	Nels'n's yd.
Material	white-burning	red-burning	cream-burn'g clay	so-called fire clay
Lab. No.	1069	1075	1076	1181
Water required	27.5	24.2	25.8	24.2
Slaking	mod. fast	....	fast	....
Plasticity	good	high	high	very high
Grit	some, coarse	none	some, fine	....
Air shrinkage	6.2	6.4	8.2	5.5
Average tensile strength	....	....	....	238
Maximum tensile strength	....	....	....	280
Wet-molded bricklets—				
Cone 010:				
Fire shrinkage	.1	.0	.4	.4
Color	pink	lt. red br'n	light brown	pink buff
Absorption	22.72	16.82	22.14	24.43
Cone 05:				
Fire shrinkage	1.3	.6	1.7	.4
Color	cream pink	light red	pink cream	buff
Absorption	19.18	14.56	21.85	24.90

Cone 03:				
Fire shrinkage	2.2	2.6	2 4	.6
Color	light brown	light brown	cream	buff
Absorption	14.36	10	20.61	25.12
Cone 1:				
Fire shrinkage	5.7	7	....	6
Color..................	light brown	green bro'n	green'h yel.	deep buff
Absorption	4.18	28	0	13.74
Steel hard at cone	03	03	....	1

1069. This is a buff-burning brick clay which burns to a buff brown rather than a light cream as most of the calcareous clays do. It gives a fairly hard though porous body even at cone 010.

1075. This clay burns to a good color and will probably make a good dry-press body. It gives a fairly good body when molded soft-mud at 010 but should be burned preferably at 05. At cone 1 it is past vitrification.

1076, a porous clay of irregular structure and very little grit and probably would not stand more than cone 2.

Forestville, Door Co. One clay pit has been opened up by the Door County Mfg. Co. The upper part of the bank consists of laminated clay and sand showing a thickness of 8 feet and this is underlain by blue clay which extends to a depth of 40 feet. It is supposed that the blue clay is underlain by gravel. The physical properties of the brick mixture (Lab. No. 1071), are water required, 22 per cent; slaking, slowly; plasticity, high; grit, some very fine; air shrinkage, 5.5.

In burning it behaved as follows:

Wet-molded bricklets:			
Cone...........................	010	05	1
Fire shrinkage	0	sl. sw.	8.6
Color..........................	pink buff	deep buff	drab
Absorption.....................	20.25	17.87	0
Steel hard at cone.	1.6	....	....

Steel hard at cone 1.

Uses. The clay at the present time is employed for the manufacture of common brick, a mixture of 1-3 of the upper clay and 2-3 of the lower clay being used. The clay is prepared in a pug mill and Potts crusher, and then put through a stiff-mud side-cut machine. Drying is done under sheds and burning in scove kilns.

Antigo, Langlade Co. There are three yards here operated by the Antigo Clay Co., Mr Myers, and Ed. Grabowskie, respectively.

The clay deposit here is probably of glacial type, being rather shallow in its character,, and containing more or less pebbles which have to be removed by screens. One sample was tested from the yard of Mr. Grabowskie (Lab. No. 1101), and showed the following characters: water required, 19.8 per cent; slaking, moderately fast; plasticity, fair; grit, coarse; air shrinkage, 3.8 per cent.

In burning it behaved as follows:

Wet-molded bricklets:					
Cone	010	05	03	1	3
Fire shrinkage	sl. sw.	sl. sw.	.6	4.3	6
Color	brownish yellow	light yellow	yellow brown	brown	deep brown
Absorption	16.15	15.72	13.91	4.8	.12

Superior, Douglas Co. Buff-burning clays outcrop at a number of points west and southwest of Superior, and are well exposed along the Nemadje River. One of these deposits was sampled from an outcrop two miles north of Dedham the latter town lying ten miles southwest of Superior. The properties of this (Lab. No. 1097) were as follows: soluble salts, .68; water required, 28.6; slaking, moderately fast; plasticity, good; grit, some coarse; air shrinkage, 4 per cent; average tensile strength, 159.9 pounds per square inch with a maximum of 184 pounds per square inch.

In burning it behaved as follows:

Wet-molded bricklets:					
Cone	010	05	03	1	2
Fire shrinkage	sl. sw.	0	.4	0	15
Color	cream	cream	cream	cream	drab
Absorption	33.56	33.68	32.78	28	.30

Steel hard at cone 1.

Dry-press bricklets:		
Cone	05	1
Fire shrinkage	sl. sw	0
Color	light buff	buff
Absorption	34.80	32.24

This is a good common-brick clay and there seems to be no reason why material of this type should not be utilized to supply the city of Superior and neighboring towns with building brick of the kind of which is now being sent in from Minnesota. The chemical composition of this clay is as follows:

Silica (SiO_2)	44.36
Alumina (Al_2O_3)	9.76
Ferric oxide (Fe_2O_3)	3.34
Lime (CaO)	14.48
Magnesia (MgO)	6.40
Potash (K_2O)	1.13
Soda (Na_2O)	1.34
Titanic acid (TiO_2)	.04
Loss on ignition	18.69
Total	99.54
Total fluxes	26.69

Discussion of chemical analyses. In the following table there are given the complete analyses of 15 clays, and a partial analysis of one other. These are interesting as showing the rather wide range in composition to be found among them. As might be expected they are nearly all rather low in silica and alumina as compared with the red-burning clays, and usually high in lime, although here they show much variation as can be seen by inspection of the percentages in the last three lines of the table. It is evident that the magnesia exercises a similar effect to the lime in its coloring action, for in some as 1051, and 1164 the excess of lime over iron does not appear to be sufficient to counteract its red color. The high percentage of alkalies in many no doubt assists in lowering their fusion point. Some,, as Nos. 1080, and 1164 show a rather low magnesia percentage and could no doubt be used in portland cement manufacture.

Analyses of cream-burning clays.

Lab No.	Locality.	Silica (SiO_2)	Alumina (Al_2O_3)	Ferric oxide (Fe_2O_3)	Lime (CaO)	Magnesia (MgO)	Potash (K_2O)	Soda (Na_2O)	Titanic acid (TiO_2)	Loss on ignition.	Total.	Total fluxes.	Analyst.
1010	Whitewater	32.48	7.31	4.37	18.44	7.18	2.01	.48	.12	27.70	100.09	32.48	V. Lenher.
1011	Whitewater	42.28	8.26	3.84	13.05	6.01	2.51	.49	.05	22.07	100.56	25.90	V. Lenher.
1072	Kenosha ...	38.62	8.75	8.22	14.04	6.27	2.65	.89	.07	19.99	99.50	32.07	
1115	Racine	47.36	6.98	6.68	13.10	4.36	1.28	0.68	.14	19.05	99.63	26.10	
1051	Burlington.	41.86	14.31	6.69	9.38	4.75	3.73	.92	.05	17.86	99.55	25.47	
1080	Milwaukee.	37.76	9.07	3.60	22.48	2.84	2.07	.54	.38	21.52	100.26	31.53	
1143	Port Washington....	42.52	9.58	4.11	14.52	5.33	2.59	1.04	.07	19.49	99.25	27.59	
1148	Sheboygan.	36.95	6.70	3.60	20.55	8.95	1.31	1.13	.12	21.22	100.53	35.54	
1153	Manitowoc.	41.70	11.29	2.77	15.40	3.32	3.05	1.27	.38	19.84	99.02	25.81	
1155	Manitowoc.	41.53	10.02	5.00	14 33	4.24	4.39	.55	.10	19.52	99.68	28.51	
.....	Manitowoc.	39.04	13.60	3.44	14.81	7.33	2.55	1.08	....	18.87	100.72	29.21	E. G. Smith.
1119	Milladore...	52.60	12.60	3.82	12.77	3.22	....	....	....	12.49	....	....	A. S. Mitchell.
1046	Green Bay..	43.58	11.99	4.63	13.04	4.20	3.17	3.13	....	16.74	....	28.14	
1084	Green Bay..	44.92	12.71	5.40	12.06	4.91	3.08	1.23	.09	15.84	100.24	26.68	
1164	Shawano...	59.56	10.19	4.68	8.28	2.64	2.58	.80	.07	11.14	99.94	18.98	
1097	Superior....	44.36	9.76	3.34	14.48	6.40	1.13	1.34	.04	18.69	99.54	26.69	
	Minimum...	32.48	6.70	2.77	8.28	2.64	1.23	.48	.04	11.14	....	18.98	
	Maximum .	59.56	14.31	8.22	22.48	8.95	4.39	3.13	.38	27.70	....	35.54	
	Average ...	42.94	10.19	4.63	14.42	5.12	2.53	1.03	.12	18.50	....	27.98	

Discussion of physical properties. A sufficient number of physical tests were made to give an excellent idea of the character of the cream-burning non-refractory clays occurring in Wisconsin. The results of these tests have been tabulated in the table at the end of the report and an inspection of them shows the following.

The majority of those whose slaking qualities were tested slake fast.

Nearly all of the clays examined show at least good plasticity and some show a high plasticity.

The percentage of water required for mixing ranged from 15.4 per cent to 31.9 per cent, with an average of 21.5 per cent figured on 66 samples. Twenty-six of these took under 20 per cent, and twenty-three others required under 25 per cent, so that the amount of water required for mixing is not excessive.

The air-shrinkage showed great variation, ranging from 1.6 per cent to 10.9 per cent with an average of 5.8 per cent. In the majority of samples it ranged from 5 to 7 per cent. The use of a mixture of clays, sometimes lowered the air shrinkage. (See Watertown, 1063, and 1111, Merrimac, 1162, 1171.) In other cases the air shrinkage was no lower in the brick mixture than in the individual clays, but in such instances advantages were gained in the density of the brick in burning.

The average tensile strength of 27 samples tested ranged from 64 lbs. per square inch to 230.2 lbs. per square inch. Twenty-one of the clays examined showed a tensile strength of over 200 lbs. per square inch, while five others exceeded 150 lbs. per square inch. The tensile strength does not appear to prevent cracking due to rapid drying as some of the clays with a high strength had to be dried slowly. However it should be remembered that the clay is still comparatively soft when some of this air cracking occurs, and its tensile strength at that time is not as high as when thoroughly air-dried.

It is in the fire tests however that the greatest variation is to be seen.

All samples were burned at Cones 010, 05, 03, 1, and at 2, 3, and 5 if they were not too fusible.

At cone 010, the shrinkage was uniformly low, and in some cases there was even a slight swelling; the color was commonly cream or pink, and the absorption usually high.

At cone 05, the shrinkage was still low, and sometimes even a minus quantity. The color was usually buff or cream, and the absorption in most cases still high. Five clays burned steel hard at this cone.

At cone 03 a few of the clays still showed slight swelling, but the fire shrinkage of the majority had increased somewhat, and 10 additional ones had reached steel hardness.

At cone 1, some of the clays showed a great increase in shrinkage because it was approaching its point of viscosity, and the absorption of the others burned at this cone was in many instances quite low. Several even became viscous at cone 1.

All of the samples were not burned above this cone, only the more important ones being fired higher, and it is seen from these that not a few do not reach a condition of viscosity until heated up to cone 5.

Some of the burning tests are tabulated below.

Cone	010	05	03	1
Min. fire shr.	0	0	0	0
Max. fire shr.	1.7	2.6	4.6	13.6
Min. absorption	16.15	15.72	7.41	0
Max. absorption	42.58	37.20	36.90	35.92
Number burning steel hard	none	3	9	15

Summary of properties of cream-burning clays. The cream-burning clays agree more or less closely in their color-burning qualities, some burning to a lighter cream and others to a darker cream. They all show a low shrinkage until burned nearly to their point of vitrification, when the shrinkage suddenly increases from 1 per cent or less up to 7 or even 12 per cent, and from this point they change rapidly to a viscous condition. This rapid softening of the clay is one thing which would interfere with the use of these clays for the manufacture of vitrified brick. All the clays of this group burn to a rather porous body, due partly to the fact that they contain a high percentage of lime carbonate which in burning loses its carbon dioxide leaving the brick quite porous up to the vitrifying point. Most of them burn to a very good brick.

Here, however, the similarity between the clays of this class ends. They show considerable variation in the temperature at which they become steel hard, some reaching this condition at as low a cone as 05, while others do not attain this degree of hardness until cone 1 or even 3. A similar variation is shown in their melting points. Among the most easily fusible were some from Green Bay, Burlington and Granville, which showed signs of viscosity at cone 1, while others like those from Milwaukee, Whitewater, Kewaunee, Madison, etc., became viscous at cone 5 or higher. The reason for this difference in their fusion points is to be found on comparing their composition, the more easily fusible ones containing a higher percentage of fluxing impurities. In the case of those clays having the higher fusion point, it is necessary to burn the bricks to a correspondingly higher temperature in order to obtain a sufficiently hard product. The effect of this difference is seen in the amount of fuel required for burning the bricks.

Cones distributed among the manufacturers show that the temperature at which the cream bricks were burned ranged from cone 05 to cone 3, the melting point of the latter cone being reached in the Milwaukee kilns, and the former at Burlington.

An interesting feature in this connection is that even in the same bank the clay in different layers may show a difference in fusibility. At Burlington the yellow top clay becomes viscous at cone 5, while the lower blue clay reaches the same condition at cone 1. This is because the top clay contains less lime and other fluxes.

Uses of the calcareous cream-burning clays. The main use of these clays is, and probably will continue to be for the manufacture of common brick, but many of them lend themselves to the manufacture of dry-pressed brick, and the tests made on them show that they are of very fair strength. In addition the smoother ones work also for the manufacture of drain tile. There is no hope of their being used for paving brick manufacture. On account of their high plasticity it is possible to utilize them in common earthenware manufacture. They could also be utilized to some extent for making art pottery. Experiments made on the more plastic ones show that they can be either turned on a wheel or cast, and covered with a majolica glaze.

A few as mentioned under slip clays melt to a fair glaze, and there are strong possibilities that careful search may demonstrate the occurence of slips at other localities within the state.

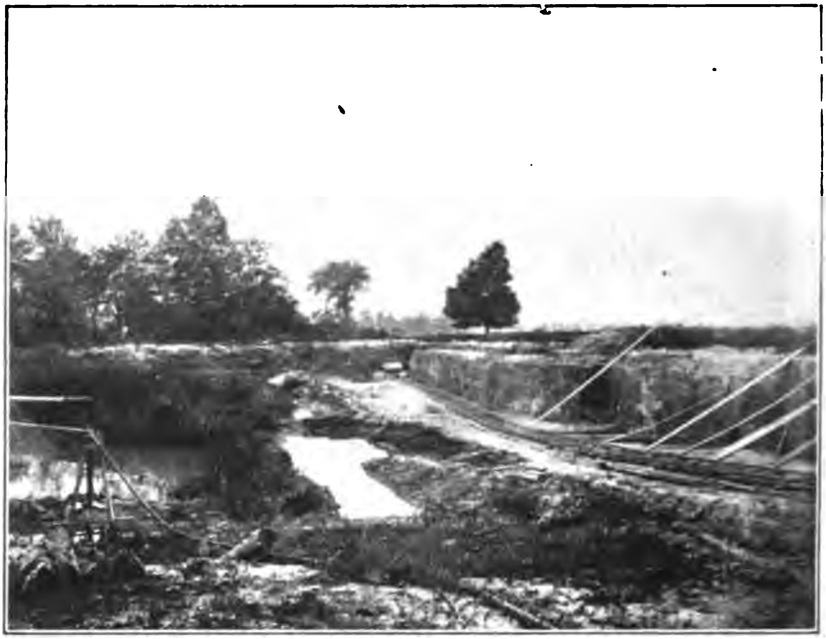


Fig. 1. Zerrenner Bros.' clay bank, New London. An estuarine deposit.

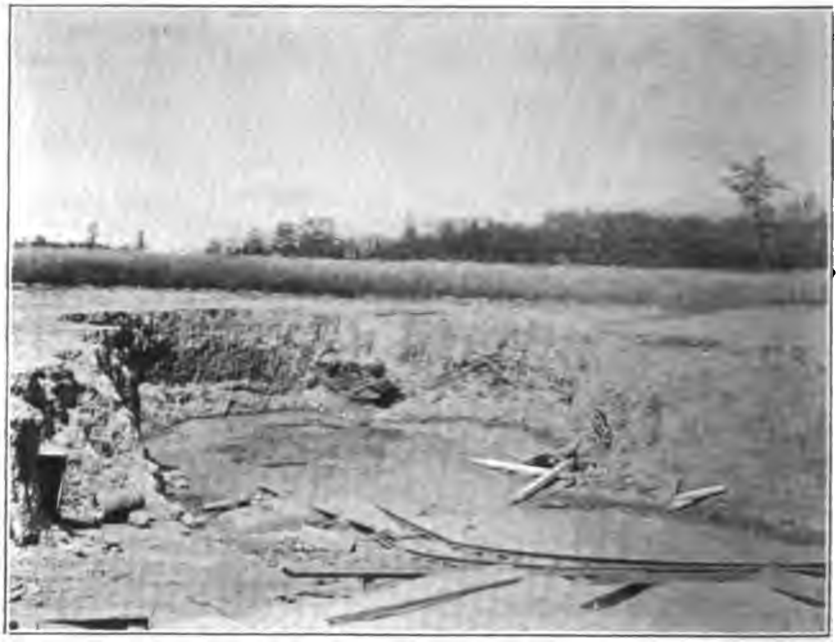


Fig. 2. Clay pit of Stevens Point Brick and Construction Co. A pit in residual clay. The overburden is one foot of soil.

II. RED AND BROWN-BURNING CLAYS. These, while not as widely distributed, represent probably fully as important a group of Wisconsin clays as the cream-burning ones. Roughly speaking, we may say that their distribution covers the western, central and much of the northern portion of the state, but the deposits are not always as thick or as extensive as those of the cream-burning clays. To the east and northeast they overlap the area of cream-burning clays, and even occur at times within the area of the latter. In such cases they commonly represent the upper or leached beds of the cream-burning deposits.

1. THE RESIDUAL CLAYS. These represent a clay resource not yet thoroughly investigated or developed, although the deposits underlie a large area as shown in Plate II, but are worked only at Stevens Point, Grand Rapids, Ringle, and Halcyon. At all of these localities except the last mentioned it is the more gritty phases that are used, but not the most gritty ones found in this area, for we find that the clays range from very sandy ones having many coarse angular sand grains to others which are quite fine and free from grit. Now while the gritty phases may burn to a good red color, and they often do, it is impossible to make them burn to a good dense vitrified body, no matter how hard they are fired, because there are not enough fine clayey particles in the material to thoroughly fill up the spaces between the sand grains. This statement is not to be taken as meaning that these gritty clays are fire clays, for they are by no means such, since many of them fuse at cone 1. There are, however, clays in the residual area which do burn to a pretty dense body and which appear to be worth experimenting with for the manufacture of paving brick.

As an example of the extremes in variation that are found we may take three clays, two of them from Stevens Point, and the third from near Pittsville. Their fire shrinkage and absorption at different cones are as follows:

Cone.	STEVENS POINT.		STEVENS POINT BRICK YARD.		PITTSVILLE.	
	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.
010......	.4	17.60	.6	14.30	2.3	11.32
05......	.4	15.64	2 0	12 60	4.7	6.22
1......	3.3	8.02	5.7	4.29	7.	2.27

The clay from Pittsville is one of the most dense-burning found in the residual area. It also burns to a good color.

Detailed description of occurrences. Samples of the residual clays were collected from about 26 localities, and the detailed notes on these occurrences are given below, this being followed by a summary of the results obtained.

Lake Ennis, Marquette Co. The diorite which outcrops on the Taylor farm, 12 miles northeast of Portage, is covered in places by a deep red residual clay, a sample of which was taken from the hillside near Lake Ennis in Marquette Co. It is a very plastic, dense-burning clay, but in most places appears to contain too many angular fragments of undecomposed rocks. A physical test made of the material (Lab. No. 1178) showed that it slaked slowly, and worked up with 22 per cent of water to a somewhat gritty mass of good plasticity. The soluble salts in it amounted to .42 per cent. The air shrinkage was 4.9 per cent and the average tensile strength 118 pounds per square inch with a maximum of 134 pounds per square inch.

In burning it behaved as follows:

Wet-molded bricklets:					
Cone	010	05	03	1	2
Fire shrinkage, per cent....	1	1.7	2.3	5	viscous
Color	red	dark red	dark red	dark brown	....
Burns steel hard at cone 03.					
Absorption, per cent.......	13.63	12 22	8 53	2.31	....

Dry-press bricklets:		
Fire shrinkage, per cent	1.33	4 66
Color	light brown	brown
Absorption, per cent	13.80	2.60

Halcyon, Jackson Co. The partly decomposed schists which are used at this locality, outcrop along the banks of the Black river. While the material has not weathered completely to a clay and still retains its schistose structure, yet on storage under sheds, it mellows down considerably, owing to the fact that most of the feldspathic element in it has decayed. That it is sufficiently decayed to yield a mass of good plasticity is shown by the physical tests.

As the pit was filled with water, the stock of clay under the drying shed was sampled for testing with the following results. The clay (Lab. No. 1035) slakes slowly and worked up with 19.8 per cent water to a mass of excellent plasticity, but containing both coarse and fine grit particles. Its air shrinkage was 4.36 per cent, and the average tensile strength 203 pounds per square inch, with a maximum of 230 pounds per square inch. While it stands hot air drying, still this cannot be done too rapidly as the clay shows a tendency to develop some small cracks. In burning it gave the following results:

Wet-molded bricklets:					
Cone	010	05	03	1	3
Fire shrinkage, per cent	sl. sw.	1	3	4.5	5.7
Color	brown buff	red	red	red brown	dark brown
Absorption, per cent	15.15	11.11	8.77	5.25	3.84

Silica (SiO_2)	60.44
Alumina (Al_2O_3)	19.74
Iron oxide (Fe_2O_3)	6 23
Lime (CaO)	.40
Magnesia (MgO)	2.22
Potash (K_2O)	4.03
Soda (Na_2O)	1.89
Titanic acid (TiO_2)	.06
Ignition, loss	5.60
Total	100.61
Total fluxes	14.77

Uses. The clay is being used at the present time for the manufacture of dry-pressed and stiff-mud brick. Some hollow brick are also being made. It is necessary to grind the clay in dry pans, and temper it in pug mills, while the drying is done in tunnels, and the burning in either rectangular or circular down-draft kilns. The product from the yard of the Halcyon Pressed Brick Works yielded good results on testing.

Merrillan, Jackson Co. Residual clays derived from the Potsdam formation, have been found below the surface at many points around Merrillan, but as pointed out by Dr. Buckley in an earlier bulletin, they had not been utilized up to that time, nor have they been even up to the present. The clay is usually quite plastic, but contains some scattered layers of shaly sandstone, which, however, will crush up rather easily. Test pits dug at a number of points in this region have shown the presence of the clay. One sample (Lab. No. 1041) was taken from the Davidson place, on the N. W. 1/4 of the N. W. 1/4, section 25, township 23 N., R. 4 W. The clay is quite plastic. Another sample was collected from a test pit on the Richmond place, located on its middle forty and along the line of Richmond's fence. This clay (Lab. No. 1042) contained streaks of greenish micaceous clay but was also quite plastic. The physical properties of the two are given below:

Location	Davidson property	Richmond property
Laboratory No.	1041	1042
Water required	27.5	27.5
Plasticity	good	fair
Grit	some, fine	mixed
Air shrinkage	6.6	5.5

They behaved as follows in burning:

Laboratory No.	1041	1042
Wet-molded bricklets—		
Cone 010:		
Fire shrinkage	1	0
Color	light red	light red
Absorption	13.82	13.49
Cone 05:		
Fire shrinkage	2.7	.6
Color	light red	light red
Absorption	9.38	10.14
Cone 03:		
Fire shrinkage	4.6	2.3
Color	red	red brown
Absorption	6.33	6.59

Cone 1:		
Fire shrinkage	8	7.4
Color	dark brown	brown
Absorption	1.35	1.94
Cone 2:		
Fire shrinkage	7	7.7
Color	chocolate	dark brown
Absorption	1.31	1.40
Cone 5	viscous	

1041. This clay burns steel hard at cone 03, and gives an excellent hard brick, with low absorption. At cone 1 it is nearly vitrified, and appears to be one of the most promising clays tested.

1042. This clay burns steel hard and nearly vitrified at cone 1, and appears to be slightly more fusible.

The chemical composition of the clay 1041 from the Davidson place is:

Silica (SiO_2)	63.21
Alumnia (Al_2O_3)	18.00
Ferric oxide (Fe_2O_3)	4.62
Lime (CaO)	.18
Magnesia (MgO)	1.12
Potash (K_2O)	9.11
Soda (Na_2O)	.57
Titanic acid (TiO_2)	.05
Loss on ignition	3.61
Total	100.47
Total fluxes	15.60

This analysis shows a curiously high percentage of potash, and would indicate a lower fusibility than the clay actually shows.

Milladore, Wood Co., (Lab. No. 1085). Much clay is found underlying the surface around this locality, the properties of which are shown in part at least by tests made on samples taken by Mr. F. H. Merrell. One of these was taken from the western end of the Hooper property, this land lying on the south side of the Wisconsin Central railroad and immediately west of the village. The sample was taken with an 8 inch auger to a depth of 12 feet, and represents the average of the entire boring. There is 5 feet of surface clay over-burden, similar to that over sample 1088 described further on. The boring made did not reach the bottom of the clay deposit. The clay is of brown color when moist, and slakes moderately fast. With 28.6 per cent of water it works up to a gritty mass of high plasticity. The soluble salts in the clay amounted to .39 per cent and the air shrinkage was 8.4 per cent which is rather high, but a large brick made of the clay stood rapid drying without cracking. The average tensile strength was 186 pounds per square inch with a maximum of 251 pounds per square inch. In burning the clay behaved as follows:

Wet molded bricklets:				
Cone	010	05	03	2
Fire shrinkage	3.4	5.6	6.4	6
Color	red	dark red	dark red	brown
Absorption	8 33	4.61	2.73	.50

Dry-press bricklets— Cone 05:	
Fire shrinkage	3.33
Color	brown
Absorption	13.93

The clay gives an excellent hard body and is one of the best red-burning brick clays seen in the residual area. The wet-molded bricklets burned steel hard at cone 05 and the dry-press bricklets gave a very fair body at this cone. The clay fused above cone 2.

The chemical composition of this material as analyzed by A. S. Mitchell of Milwaukee was:

Silica (SiO_2)	53.18
Alumina (Al_2O_3)	14.92
Ferric oxide (Fe_2O_3)	14.64
Lime (CaO)	1.09
Magnesia (MgO)	2.53
Loss on ignition	8.07
Total	94.41

Uses. The clay has not been used up to the present time but is no doubt excellently adapted to the manufacture of red brick. It is not sufficiently fine grained, however, to be used for drain tile or common earthenware.

The second sample (Lab. No. 1088) tested from the Hooper property was made up from a number of samples taken from the borings ranging from the surface to the residual clay under-

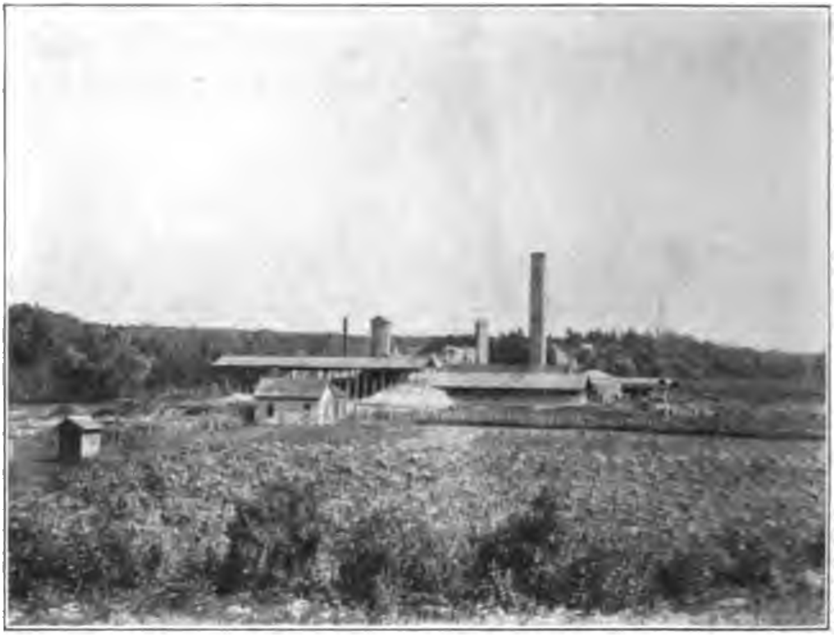


Fig. 1. General view of Riverside Brick Works at Halcyon.

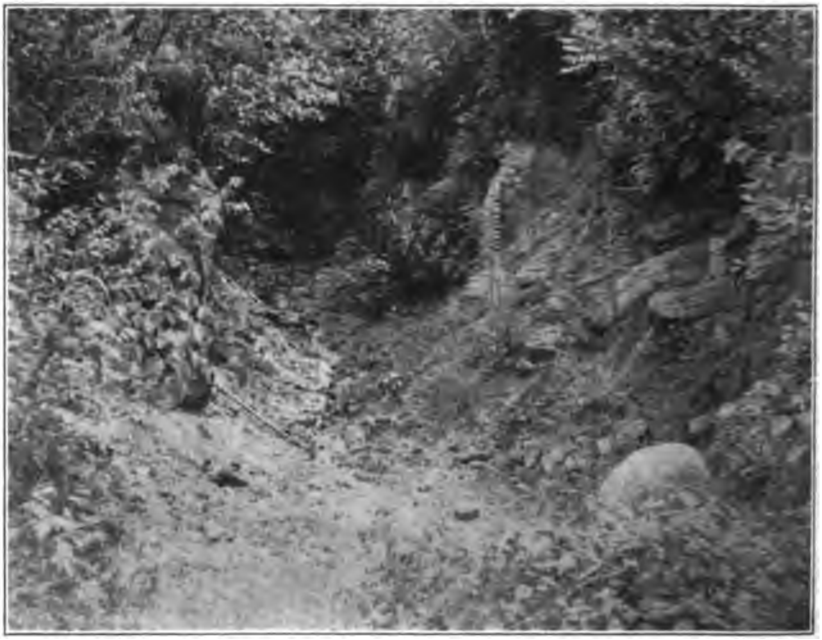


Fig. 2. Cut in residual clay six miles east of Eau Claire. Shows Potsdam sandstone overlying the clay.

neath the latter being found at a depth varying from 4 to 7 feet. This sample which was light brown in color when moist, and slaked slowly, working up with 18.7 per cent of water to a mass of good plasticity but containing much coarse grit. Its air shrinkage was 7.4 per cent, but the tensil strength was not determined. The wet-molded bricklets in burning behaved as follows:

Cone	010	05	1
Fire shrinkage	0	1	3.6
Color	red brown	red brown	red brown
Absorption	10.80	8.62	1.24

This material although a coarse grained clay containing a number of partially decomposed mineral grains would serve for the manufacture of common brick. If mixed in equal proportions with sample number 1131 from Pittsville it yields an excellent hard body at cone 1.

A third sample (Lab. No. 1087) taken from the eastern end of the Hooper property, and representing the average of several 8 inch borings 10 feet deep developed the presence of an additional quantity of good brick clay. This was a dark-brown clay with .33 per cent of soluble salts, and slaked moderately fast. It worked up with 26.7 per cent of water to a mass of low plasticity and much grit, whose air shrinkage was 5.1 per cent and the average tensile strength 121 pounds per square inch with a maximum of 166 pounds per square inch. A large brick made from the sample stood fast drying without cracking.

In burning it behaved as follows:

Wet-molded bricklets:					
Cone	010	05	03	1	2
Fire shrinkage	2	2.7	6.7	7.3	8
Color	red	red	dark red	dark red	brown
Absorption	17.77	13.54	7.79	4.48	4.14

Dry-press bricklets—		
Cone 05:		
Fire shrinkage	0	3.33
Color	light brown	brownish red
Absorption	15.17	8.72

Uses. The material is not now worked, but is evidently a good red-burning common-brick clay, and at cone 1 burned to a very hard bricklet of rather deep color. Common brick could be burned from it at as low a temperature as cone 010 and dry-press bricklets probably at cone 05.

The chemical analysis of this sample made by S. B. Newberry was as follows:

Silica (SiO_2)	64.88
Alumina (Al_2O_3)	17.90
Ferric oxide (Fe_2O_3)	5.40
Lime (CaO)	.60
Magnesia (MgO)	1.40
Loss on ignition	5.64
Total	95.87

This would indicate it to be a siliceous red-burning clay.

Grand Rapids, Wood Co. An outcrop of residual clay occurs at South Centralia just near the bridge of the Wisconsin Central Railroad spur running out to the pulp mill. Its exact location is S. W. corner section 18, township 22 N., R. 6 E. The clay which has been formed by the weathering of diorite of pre-Cambrian age shows an average depth of about 8 feet, but the lower part contains numerous fragments of partially decomposed rock, the bed rock outcropping along the river about 8 to 10 feet above the river level. A sample of this clay (Lab. No. 1001) was collected and put through the physical and chemical tests with the following results: Color when moist, deep red; soluble salts, .12; slaking slowly. It mixes up with 27.5 per cent of water to a mass of fair plasticity and containing some coarse grit, whose air shrinkage is 5.3 per cent, and whose average tensile strength is 96 pounds per square inch with a maximum of 121 pounds per square inch.

In burning it behaved as follows:

Wet-molded bricklets:				
Cone	010	05	03	1
Fire shrinkage	.3	2.7	4.3	6.6
Color	light red brown	red brown	red brown	red brown
Absorption	19.62	15.40	11.38	7.08

Dry-press bricklets:

Fire shrinkage	5.5
Color	red brown
Absorption	17.22

This clay burns to a good brick body even at cone 010 but above cone 05 the color of the clay deepens. It shows no signs of fusing at cone 1, and did not yield a vitrified body.

The chemical analysis made by Professor Lenher gave:

Silica (SiO_2)	52.33
Alumina (Al_2O_3)	17.61
Ferric oxide (Fe_2O_3)	15.94
Lime (CaO)	2.25
Magnesia (MgO)	.25
Potash (K_2O)	.93
Soda (Na_2O)	.23
Titanic acid (TiO_2)	.04
Loss on ignition	10.38
Total	99.96
Total fluxes	19.60

This analysis shows a high percentage of ferric oxide which is responsible for the deep red color to which the clay burns. The percentage of alkalies for such an impure clay is, however, rather low.

Uses. This clay is not being worked and it is doubtful whether it would be valuable for anything better than common brick. Its irregular depth is unfortunate, but there is probably sufficient material to supply a small brick yard.

Sigel Station, Wood Co. (Lab. No. 1002.) A deposit of residual clay is being worked at the plant of the Grand Rapids Brick Company located 3 miles northwest of Grand Rapids in the S. W. ¼ of the S. W. ¼ of section 36, township 23 W., range 35 E. The clay bank is a shallow bed lying about 400 feet northwest of the works, and showing a depth of 6 feet. The lower clay in the pit is blue and has resulted from the decomposition of diorite while the upper clay which is said to be gray burning and of low shrinkage is in part at least of glacial origin. Between the two clays is a thin layer of tough red clay which is also residual in its character.

The physical properties of the lower clay are as follows: Soluble salts, .38; water required, 28.6. It slakes fast and mixes up to a mass of high plasticity with some coarse grit.

The air shrinkage is somewhat high being 7.5 per cent, and the average tensile strength is 227 pounds per square inch with a maximum of 254 pounds per square inch.

In burning it behaved as follows:

Wet-molded bricklets—				
Cone	010	05	03	1
Fire shrinkage	.8	1.7	4	7
Color	light red	dark red	light brown	dark brown
Absorption	12.62	10.27	6.05	1.02

Dry-press bricklets—		
Fire shrinkage	1.33	6.33
Color	reddish brown	red brown
Absorption	14.26	1

The chemical composition of this clay is:

Silica (SiO_2)	54.74
Alumina (Al_2O_3)	16.62
Ferric oxide (Fe_2O_3)	10.27
Lime (CaO)	.36
Magnesia (MgO)	1.73
Potash (K_2O)	6.26
Soda (Na_2O)	1.72
Titanic acid (TiO_2)	.05
Loss on ignition	7.87
Total	99.62
Total fluxes	20.34

This is to be regarded as a good red-burning common brick clay which even at cone 010 is capable of making a brick with a good ring to it. At 05 the color deepens to an undesirable degree. It is too coarse to develop a vitrified body, and is by no means refractory as at cone 1 it begins to show signs of viscosity.

Uses. The clay is now being mixed with the top clay and used for the manufacture of common brick. It is molded in a soft-mud machine, dried on pallets and burned in Dutch kilns. In burning it settles 2 to 4 inches in 42 courses. The product showed up well on testing.

Another locality near Grand Rapids at which the residual clays are being worked is at the yard of J. N. Lessig & Son, (Lab. No. 1003) located in the S. W. ¼ of the N. W. ¼, section

29. township 23 N., range 6 E. This point is about three miles north of Grand Rapids. The material, as already stated, is a residual clay which is somewhat similar to that used at the other brick yard but at the time of the writer's visit the excavation was so full of water that no definite data could be obtained regarding it. Its properties however as obtained by testing a sample of the green brick were as follows: Color when moist, dark red; water required, 25.3; slaking slowly.

Although the clay contains much coarse grit it has a high plasticity. The air shrinkage of the bricklets tested was 6.65 per cent and the average tensile strength was 165 pounds per square inch with a maximum of 190 pounds per square inch.

In burning it behaved as follows:

Wet-molded bricklets:				
Cone	010	05	03	1
Fire shrinkage	0	1.7	2	5.4
Color	red	red	deep red	deep red
Absorption	10.23	10.53	8.16	2.39

The clay burns steel hard at cone 03, and yields a good hard brick but has too much coarse grit to produce a vitrified body. At cone 1 it is not far from viscosity.

Uses. The clay is worked for common bricks, being molded either stiff or soft mud, dried in tunnels and burned in up-draft kilns.

Pittsville, Wood Co. This locality also lies within the residual belt, and the residual clay deposits underlie a considerable area surrounding the town of Pittsville. Some testing has been done on the property of Mr. Nash Mitchell located just southeast of Pittsville on the main road to Dexterville. Three holes have been dug to the south, one in the middle and one on the western side of the track. The first hole at the south edge was dug to a depth of 6 feet, the one in the middle to about 5 feet and the one to the west for 8 feet. The clay in the three holes varied somewhat. In the first hole there was an overburden of 18 inches sand and loam, under this 2½ feet of micaceous sandy clay with angular quartz fragments and below this dark red very plastic clay practically free from stones. In the second hole the clay encountered is more or less micaceous while in the third hole the clay was of a yellowish color. The yellow and red clays are thought to run to at least 6 feet in depth and underlie 35 acres.

Their physical properties were as follows: The bottom clay from hole No. 1 (Lab. No. 1131) was a very plastic material which slaked slowly and worked up with 25.3 per cent of water to a mass of high plasticity, containing some coarse grit. Its air shrinkage was 7.9 per cent.

In burning it behaved as follows:

Wet-molded bricklets:				
Cone	010	05	03	1
Fire shrinkage	2.3	4.7.	6.6	7
Color	light red	dark red brown	dark red brown	dark red brown
Absorption	11.32	6.22	3.23	2.27

The clay burned steel hard at cone 05 and becomes viscous at about 3. It burns to an excellent color and hard body and would possibly work for the manufacture of vitrified brick.

Its chemical composition is:

Silica (SiO_2)	46.34
Alumina (Al_2O_3)	16.20
Ferric oxide (Fe_2O_3)	17.75
Lime (CaO)	2.62
Magnesia (MgO)	.80
Potash (K_2O)	4.83
Soda (Na_2O)	.58
Titanic acid (TiO_2)	.05
Loss on ignition	10.51
Total	99.68
Total fluxes	26.58

A sample of the yellow clay from hole No. 3 (Lab. No. 1128) was next tested and this was found to be a coarse-grained residual clay with many small quartz fragments but not much mica. It is very porous and even at cone 1 did not give a good hard brick notwithstanding its comparatively low absorption. Its physical properties were as follows: Water required, 15.4 per cent; slaking, fast; plasticity, fair; air shrinkage, 3.7 per cent; average tensile strength, 150 pounds per square inch with a maximum of 175 pounds per square inch. In burning it behaved as follows:

Wet-molded bricklets:					
Cone	010	05	03	1	3
Fire shrinkage	sl. sw.	sl. sw.	sl. sw.	1	3
Color	yellow brown	yellow brown	yellow brown	reddish	red brown
Absorption	12.11	12.17	10.94	9.68	9.42

It did not burn steel hard until cone 3.

Dry-press bricklets:	
Fire shrinkage	0
Color	yellow
Absorption	12.68

Uses. The material is not being employed at the present time and it is doubtful whether it would work for anything else than the manufacture of common brick.

The third sample, (Lab. No. 1129) represents the clay from the lower portion of hole No. 2. This is a reddish-brown clay which is rather coarse grained and micaceous but burns to an excellent color. On account of its grittiness it took about 16.5 per cent of water to work it up and slaked slowly to a mass of good plasticity. Its air shrinkage was 4.4 per cent and its average tensile strength 180 pounds per square inch with a maximum of 202 pounds per square inch.

In burning it behaved as follows:

Wet-molded bricklets:					
Cone	010	05	03	1	3
Fire shrinkage	sl. sw	.3	0	2	7
Color	yellow brown	yellow brown	reddish brown	gray brown	brown
Absorption	12.54	11.77	10	9.50	9.26
Steel hard at cone 1	1	....	....	....	....

Dry-press bricklets:	
Fire shrinkage	0
Color	brown
Absorption	13.38

The red clay from the upper part of the same section likewise burned to a fine red color but is too gritty to vitrify. This clay (Lab. No. 1130) required 22 per cent of water, and slaked to a mass of high plasticity and containing considerable grit. Its air shrinkage was 5.1 per cent. In burning it behaved as follows:

Wet-molded bricklets:				
Cone	010	05	03	1
Fire shrinkage	0	1.3	2.7	4.3
Color	pink	pink brown	red brown	red
Absorption	16.24	15.52	12.44	8.82

The clay burns steel hard at 03.

Uses. The material is not being used but while it would undoubtedly make an excellent clay brick it is too gritty to vitrify.

Springvale, Portage Co. (Lab. No. 1096.) The residual clay is found underlying the Potsdam sandstone at this locality and is also found exposed along the creeks. A sample taken from such position was secured by Mr. F. H. Merrell from the bank of a small creek on the Wisconsin Central Railroad 4 miles south of Stevens Point. The deposit is immediately above the railroad bridge and below a grist mill, on the Stevens Point and Plover highway and represents a number of shallow borings taken with an 8 inch auger. The material which is a brown residual clay of sandy character is lighter burning than most of the others in this region. It contains .31 per cent soluble salts, and works up with 28.6 per cent of water to a mass which slakes rather fast and develops fair plasticity. Its air shrinkage was 6.1 per cent, and its average tensile strength 93 pounds per square inch with a maximum of 105 pounds per square inch.

In burning it behaved as follows:

Wet-molded bricklets						
Cone	010	05	03	1	2	5
Fire shrinkage	1.4	2.6	5	6.9	7	not vitrified
Color	pink	pink	lt. red	br'wni'h	pink	
Absorption	18.08	15.94	10.91	6.40	6.40	

This indicates it to be more refractory than the majority of the residual clays tested, which become viscous at cone 1 or not far above it. It is certainly more refractory than some of the clays which are now used for Wisconsin brick and which are placed on the market under the name of fire brick. A large brick made from this clay stood rapid drying without cracking.

A chemical analysis made by Mr. A. S. Mitchell of Milwaukee gave:

Silica (SiO_2)	63.04
Alumina (Al_2O_3)	21.60
Ferric oxide (Fe_2O_3)	3.50
Lime (CaO)	.85
Magnesia (MgO	1.00
Alkalies	undetermined
Loss on ignition	5.95
Total	95.94

Stevens Point, Portage Co. This locality is surrounded by deposits of residual clay which have been opened up at two points for the manufacture of brick. The works of both companies, which are known respectively as the Langenberg Brick Company and the Stevens Point Brick and Construction Company are located on the road north of Stevens Point. At the works of the former whose exact location is in the N. E. ¼, section 19, township 24, range 8 E., the material worked is a bank of residual clay derived from the decay of a granitic schist which is cut by veins of quartz and intrusions of granite. Of these three rocks the granitic schist is the most easily decomposed and the clay formed from it shows a thickness ranging all the way from two feet to an observed maximum of 12 feet. The quartz and the granite decompose less rapidly and the former specially is apt to form stony streaks in the clay which have to be avoided or thrown out in digging. In the upper part of the section the clay is much tougher than in other parts of the bank and is due to the material having been worked over by natural processes. A certain amount of this is mixed in with the lower lying clay and improves the working qualities of the material. The varying depth which residual clays often show is well seen in this pit of which a section is given in Fig. 1.

The lower clay which contains more or less decomposed rock stands a little more heat than the top clay and consequently this is sometimes worked into brick which are incorrectly termed fire brick although they have no claim whatever to refractoriness but are sold more or less for boiler settings, and to brick makers for use in construction of the door arches of scove and Dutch kilns.

Uses. At the present time the clay is used chiefly for the manufacture of common brick and for this purpose it is put through a pair of rolls, whose main purpose seems to be to reject the stones, and then tempered in a pug mill. The clay is molded in a Sword machine and the bricks are hacked out in the open for drying. Unless the clay is properly prepared it is apt to show cracks in the air drying. The material is burned in Dutch kilns and there is a settle of about 6 inches in 38 courses. The temperature reached in burning is no higher than the fusing point of cone 010.

The plant of the Stevens Point Brick and Construction Company was opened in the summer of 1904 and is located about 1¼ miles north of town. The clay used here is also a residual clay derived from granitic schist but at the time of the writer's visit the pit was still small and not over 8 feet deep, and the solid rock had not been reached. The clay was lighter in color and not as micaceous as that at Langenberg's yard. It (Lab. No. 1177) had the following physical properties: Color when moist light brown, soluble salts .32, water 20.9, slaking fast, plasticity fair, much grit. The air shrinkage was 3.9 per cent and the average tensile strength 128 pounds per square inch with a maximum of 146 pounds per square inch. In burning it behaved as follows:

Wet-molded bricklets					
Cone	010	05	03	1	2
Fire shrinkage...........	.6	2	4.7	5.7	6.7
Color....................	brownish red	dark red	dark red	brown	brown
Absorption	14.30	12.60	8.65	4.29	1.56

Dry-press bricklets:		
Fire shrinkage	0	3 33
Color	light brown	red
Absorption.................................	16.48	10.82

The clay when wet-molded burns steel hard at a little above cone 03. It gives a good brick, however, at a temperature of cone 010 which is also the cone at which the bricks are being burned at the yard.

The chemical composition of a sample collected by Mr. F. H. Merrell and analyzed by A. S. Mitchell of Milwaukee gave:

Silica (SiO_2)	59.94
Alumina (Al_2O_3)	16.74
Ferric oxide (Fe_2O_3)	7.64
Lime (CaO)	.43
Magnesia (MgO)	1.69
Loss on ignition	3.91
Total	90.35

Uses. The clay is now employed for the manufacture of common brick which are molded on a Sword machine, dried on an open yard and burned in Dutch kilns. If not properly tempered the clay shows a tendency to crack in drying.

Residual clay (Lab. No. 1118) is also found on the property of G. A. Sherman about one mile south of Stevens Point and the sample tested represents the average of a number of borings made through a bed 4 to 5 feet thick without reaching the bottom of the deposit. The clay is overlain by about 2 feet of sand which holds more or less water. Its physical properties were as follows: Yellow when moist, 22 per cent water required; plasticity good; much grit; air shrinkage 6.29 per cent. In burning it behaved as follows:

Wet-molded bricklets:				
Cone	010	05	03	1
Fire shrinkage	sl. sw.	1.7	2.3	3
Color	deep pink	pink brown	yellow brown	light red
Absorption	14.68	13.77	11.34	7.51

The clay gives a body of good color but on account of its coarseness does not burn to a very dense body. It probably could not be used for anything better than the manufacture of common brick.

Another sample of residual clay was taken from a field just northeast of the water works, where there is a deposit at least 12 feet deep. This material (Lab. No. 1120) is dark brown in color, contains .33 soluble salts, and mixes up with 24.2 per cent of water to a mass of rather low plasticity. It slakes fairly fast and contains much coarse grit. The air shrinkage was 6.1

per cent while the average tensile strength was 176.3 pounds per square inch with a maximum of 197.3 pounds per square inch. In burning it behaved as follows:

Wet-molded bricklets:					
Cone	010	05	03	1	2
Fire shrinkage	1	1.3	3	4.9	5.6
Color	light red	medium red	medium red	dark red	red brown
Absorpt on	13.69	11.84	9.95	6	6.11

The clay burns steel hard at cone 1.

Dry-press bricklets:		
Fire shrinkage	0	4
Color	light red	speckled red
Absorption	17.18	9.53

Uses. The material is not being worked at present, but although the clay contains much mica it gives a very hard brick at cone 1. It is too gritty to be used for making vitrified wares and is also rather sandy for the manufacture of dry-press brick, but would no doubt work wet-mud.

Still another sample of residual clay was tested from the property of J. Czaplewiski, and represents an 8 inch boring 10 feet deep. The clay (Lab. No. 1176) which is of light brown color contains .31 soluble salts and slakes rather fast. With 20.9 per cent water it worked up to a mass of low plasticity and gritty character whose air shrinkage was 3.7 per cent and whose average tensile strength was 77.3 pounds per square inch with a maximum of 90 pounds per square inch. In burning it behaved as follows:

Wet-molded bricklets:				
Cone	010	05	03	1
Fire shrinkage	.4	sl. sw.	2.3	3.3
Color	light red	light red	red brown	red brown
Absorption	17.60	15 64	18 67	8.02

The clay is too sandy to be of any use except for the manufacture of common brick and is also too sandy to work dry-press.

Eau Claire, Eau Claire Co. In Dr. Buckley's report on the clays of Wisconsin* a mention was made of the occurrence of extensive deposits of residual clay along the Eau Claire river east of Eau Claire and a number of outcrops were visited for the purpose of collecting samples to be tested for the present report. The samples came mostly from the S. E. ¼ of the N. E. ¼ of section 27, range 8 W., but the clays outcrop at a number of points in the river bank, and on the abutting slopes, on both sides of the Eau Claire river. While these clays appear to have been derived from a variety of rocks, the parent formation is mostly a schist. The depth of the deposits is variable and with the exception of a belt underlying the lower terrace bordering the river they are usually covered by a thick deposit of sand between which and the clay there is often a bed of hard sandstone. The latter, however, would make a very bad roof for underground mining operations since it is cracked by joint planes, and as soon as the underlying clay is removed the blocks of sandstone being deprived of their support will cave in.

While the majority of residual clays in this locality are rather sandy in character, some of them are quite highly plastic, and although the highly plastic ones were not found in very large quantities some of them were tested for the purpose of serving as standards for comparison in case larger deposits of the same character were found.

About 6 miles east of Eau Claire an artificial cut has been made into the hillside exposing the contact of the Potsdam sandstone and the underlying residual clays (Pl. XI, Fig. 2.)

This cut is located on the N. E. ¼ of section 21, township 27, range 8 W. Immediately underlying the sandstone at this point there is a deposit of very plastic rather dense-burning clay (Lab. No. 1033) which, however, is not present in sufficient quantities to be of commercial value, but as already stated a sample was tested for purposes of comparison if necessary.

This had the following physical properties, color when moist brown, water required for tempering 39.6 per cent, slaking moderately fast, plasticity excellent, grit low. Its air shrinkage is 10.4 per cent and the average tensile strength 339 pounds per square inch with a maximum of 454 pounds per square inch. In burning it behaved as follows:

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*E. R. Buckley, Clays and Clay-Industries of Wisconsin. Wis. Geol. & Nat. Hist. Survey, VII, pt. 1, p. 37, 237.

Wet-molded bricklets:				
Cone	010	05	03	1
Fire shrinkage	2	6.7	7	viscosity beginning
Color	light red brown	deep red	deep red	
Absorption	12.19	1.89	.50	

While the clay burns to a vitrified body still it fuses at a rather low temperature and has too high an air shrinkage to permit its being used alone, neither did it give as good a vitrified body as some of the samples tested from Pittsville and Merrillan.

In the same cut in which this clay was obtained there is a small vein of whitish clay which from inspection appears to be refractory but on which the physical tests gave results that were rather disappointing. This vein is not over 6 feet wide and considering its character is not of sufficient value or extent to make it worth while working. The physical properties of the material (Lab. No. 1032) were as follows: water required 31.9 per cent, plasticity high with little grit, slaking slow. Its air shrinkage was 8.3 per cent and the average tensile strength 156 pounds per square inch with a maximum of 160 pounds per square inch.

In burning it behaved as follows:

Wet molded bricklets:							
Cone	010	05	03	1	2	4	5
Fire shrinkage	1	4.7	6.3	8	8.6	8.3	well vit.
Color	pink gray	pink gray	gray buff	gray buff	dark gray	gray	
Absorption	15.37	9.82	7.28	3.41	3.10	2.82	

It burns steel hard at as low a cone as 010, and while it yields a good dense body it is not refractory.

PLATE XII.

Its chemical composition is

Silica (SiO_2)	46.08
Alumina (Al_2O_3)	34.25
Ferric oxide (Fe_2O_3)	3.34
Lime (CaO)	.45
Magnesia (MgO)	.20
Potash (K_2O)	3.25
Soda (Na_2O)	.55
Titanic acid (TiO_2)	.14
Loss on ignition	11.77
Total	100.03
Total fluxes	7.79

This would be a refractory clay were it not for the high percentage of potash and iron which it contains, the former indicating the presence of considerable undecomposed feldspar.

The third sample of residual clay from the Eau Claire river valley was taken from an outcrop of decomposed schist underlying the Potsdam sandstone near a small water fall about one half mile west of the preceding locality. This clay (Lab. No. 1031) when moist was brown and worked up with 32 per cent of water to a mass of high plasticity but rather gritty character. It slakes moderately fast and its air shrinkage was 7.4 per cent with an average tensile strength 112 pounds and a maximum of 127 pounds per square inch.

In burning it behaved as follows:

Wet-molded bricklets:						
Cone	010	05	03	1	2	4
Fire shrinkage	sl. sw.	5	6	6.6	6.3	7
Color	pink	red	deep red brown	red brown	red brown	dark red brown
Absorption	18.82	9.36	8	5	4.74	4.47

The clay burns steel hard at a little above cone 010. This material is a good common-brick clay capable of making a hard brick but not a paving brick. In burning to a hard product the color becomes too dull and deep to permit the material to be used for pressed brick. It is fairly dense-burning at a low cone.

Another sample (Lab. No. 1030) was taken from a pit in the woods a few feet southeast of the locality just described. This sample which was partially tested, mixed up with 26.4 per cent of water to a mass of good plasticity and scattered grit. Its air shrinkage was 5.1 per cent. In burning it behaved as follows:

Wet-molded bricklets:			
Cone	010	05	1
Fire shrinkage	sl. sw.	sl. sw.	4
Color	red brown	red brown	red brown
Absorption	22.37	18.15	9

The clay burns steel hard at cone 05.

It is too coarsely sandy to be used for anything except common brick but for this purpose would work all right, and might even be utilized for pressed brick.

Still another sample (Lab. No. 1034) from this region was taken from a pit along the road leading down the front of a terrace escarpment at a point about midway between localities 1031 and 1033. This clay worked up with 25.3 per cent water to a rather gritty mass of good plasticity and 6.4 per cent air shrinkage. In burning it gives the following results:

Wet-molded bricklets:					
Cone	010	05	03	1	2
Fire shrinkage	0	1.1	1.6	2.7	3.6
Color	light red	red	red	red brown	greenish brown
Absorption	13.66	11.77	10	7.21	6.19

The clay did not become steel hard until cone 1, at which temperature it gives a hard brick, and while it would no doubt make a good grade of common brick the material is altogether too sandy to make a vitrified body.

Ringle, Marathon Co. (Lab. No. 1007.) This is the most eastern locality at which the residual clays are being worked. The brick yard at which they are used lies a few hundred feet east of Ringle Station, and the clay is derived from a diorite schist. That which was being dug in 1904 is only partially decomposed material so that the structure of the rock is still quite apparent in the face of the bank. There are occasional feldspathic veins running through it and this makes sandy streaks in the clay. On the south side of the bank, at the top of the pit a much tougher clay is found but this as a rule is not sent to the brick machine.

The clay when moist is deep red gray in color, and slakes slowly. It contains .16 per cent of soluble salts and mixes up with 30.8 per cent of water to a mass of low plasticity and considerable grit. The air shrinkage is 5.9 per cent and the average tensile strength 97 pounds per square inch with a maximum of 110 pounds per square inch.

In burning it behaved as follows:

Wet-molded bricklets:				
Cone	010	05	03	1
Fire shrinkage	.7	4.4	8.3	vis. beg.
Color	yellow brown	deep red brown	dark brown	....
Absorption	12.97	7	2.50	....

The material makes a good common-brick clay but is too coarse and micaceous to permit its being used for paving brick.

Uses. At present the clay is molded into common brick being treated first in a pair of conical rolls for eliminating stones, and then in a Williams pulverizer, after which it is molded in a soft-mud machine, dried in tunnels, and burned in Dutch kilns. If the clay were more thoroughly mixed and burned slightly harder a much better product would result.

Medford, Taylor Co. (Lab. No. 1047.) About four miles due southwest of Medford along the Wisconsin river there is an outcrop of greenstone which was prospected at one time in search for iron ore. This rock has decomposed to a depth of not less than 16 feet and forms a tough reddish clay which however is not being used for any purpose. The clay outcrops for a distance of about 50 feet along the river and can also be found at several points back from the river and at most places is covered by a rather heavy mantle of glacial drift. The clay which is of a deep red color slakes rather fast and contains .10 soluble salts. It works up with 22 per cent of water to a mass of low plasticity and some fine grit. Its air shrinkage is 4.6 per cent, with a maximum of 134 pounds. In burning it behaved as follows:

Wet-molded bricklets:						
Cone	010	05	03	1	4	5
Fire shrinkage	.7	1	2.7	7.6	5.6	vis.
Color	dark red brown	dark red brown	dark red brown	red brown	dark red brown	....
Absorption	15.49	12.01	11.24	4.26	1.14	....

The chemical composition of the clay was as follows:

Silica (SiO_2)	45.65
Alumina (Al_2O_3)	18.90
Ferric oxide (Fe_2O_3)	18.00
Lime (CaO)	.86
Magnesia (MgO)	.29
Potash (K_2O)	7.66
Soda (Na_2O)	1.70
Titanic acid (TiO_2)	.03
Loss on ignition	6.55
Total	99.64
Total fluxes	28.51

This clay is not as fusible as one might expect from the high total fluxes but this is due to the fact that the active fluxes, such as lime, magnesia, and the alkalies, are present in small quantities. The material would not be of much value for brick manufacture but its use probably lies among the slip clays. At cone 1 it gives a dull reddish-brown slip.

Discussion of tests on residual clays. All of the tests which have been made on the residual clays are tabulated in the table at the end of this bulletin. Taking their different properties up in order we find that most of them slake or mix up rather rapidly when softened up with water. Different ones however, show a variable plasticity, this property ranging from high in some to low in others. The majority of them are gritty and some are even quite sandy.

The percentage of water required to mix them up varied from 15.4 per cent in case of the clay from Pittsville to 39.6 per cent in the case of a clay from east of Eau Claire. The average percentage of water required was 25 per cent and in the majority of the clays it was between 20 and 27 per cent. They also show a variable air shrinkage this ranging from 3.7 per cent up to 10.4 per cent with an average of 6 per cent. In most of them the air shrinkage is not excessive and the higher air shrinkages were usually found in those clays which required the greatest amount of water for tempering. It is not to be understood from this, however, that this rule applies to clays as a class.

The tensile strength was determined on 18 of the 26 samples tested and found to range from an average of 96 pounds per square inch up to 339 pounds per square inch with a maximum of 153.2 pounds per square inch. Considering the residual clays as a whole we can say that their tensile strength is very fair. In examining the results of the burning tests it is found that in almost every instance the residual clays worked or investigated are red-burning, some of them burning a bright red, others more of a brownish red. The fire shrinkage when burned to cone 010 is usually quite low but very few of them burned steel hard at this cone. Absorption in most cases at this cone is also moderate. At cone 05 three additional ones had become steel hard, and the fire shrinkage of the majority when burned at this cone was under 2½ per cent. Six of the twenty-six samples burned at cone 05 had a fire shrinkage in excess of 4 per cent and these in nearly every case were clays requiring more than the average amount of water for mixing, but not in every case representing a high tensile strength. The percentage of absorption at cone 05 was also fairly low. At cone 03 there was in most cases an increase in fire shrinkage as was to be expected and four additional ones had burned steel hard. The absorption percentages of the clays burned at this cone however, showed more variation than was the case at the two cones below. At cone 1 several of the clays burned to a very dense body, seven of them showing an absorption of under 3 per cent while two of them showed evidence of becoming viscous at this temperature.

In general it can be said of these residual clays that they burn to a body of good red color, moderate density, and that none of those examined could be classed as refractory materials. Their main use at present is for the manufacture of common brick and it is probable that most of them will continue to be used only for this purpose, although several occurences such as those around Merrillan and Halcyon, Jackson county, as well as from Pittsville, Wood county, burn to such a dense and hard body at cone 1 that it seems possible that they could be used for making hard brick for paving streets on which there is a moderate traffic. One clay, namely that from southwest of Medford is exceedingly ferruginous, burns to a deep reddish-brown body, and it is suggested that this could possibly be used as a dull glaze for coating terra cotta wares. The analyses of those which were examined chemically are tabulated below.

Analyses of residual clays.

Lab. No.	Locality.	Silica (SiO_2)	Alumina (Al_2O_3)	Ferric oxide (Fe_2O_3)	Lime (CaO)	Magnesia (MgO)	Potash (K_2O)	Soda (Na_2O)	Titanic acid (TiO_2)	Loss on ignition	Total	Total fluxes	Analyst.
1035	Halcyon ...	60.44	19.74	6.23	.40	2.22	4.03	1.89	.06	5.66	100.61	14.77	V. Lenher.
1041	Merrillan ..	63.21	18.00	4.62	.18	1.12	9.11	.57	.05	3.61	100.47	15.60	V. Lenher.
1085	Milladore ..	53.18	14.92	14.64	1.09	2.53	....	....	....	8.07	....	....	A. S. Mitchell
1087	Milladore ..	64.88	17.90	5.40	.60	1.15	....	....	....	5.64	....	....	S.B.Newberry
1001	S. Centralia (Gr. Rapids)	52.33	17.61	15.94	2.25	.25	.93	.23	.04	10.38	99.96	19.60	V. Lenher.
1002	Sigel Stat'n	54.74	16.62	10.27	.36	1.73	6.26	1.72	.05	7.87	99.62	20.34	V. Lenher.
1131	Pittsville ..	46.34	16.20	17.75	2.62	.80	4.83	.58	.05	10.51	99.68	26.58	R. C. Benner.
1096	Springvale.	63.04	21.60	3.50	.85	1.00	....	....	....	5.95	....	....	A. S. Mitchell
1005	Stevens Pt.	59.94	16.74	7.64	.43	1.69	....	....	....	3.91	....	....	A. S. Mitchell
1032	6 mi. e. Eau Claire....	46.08	34.25	3.34	.45	.20	3.25	.55	.14	11.77	100.03	7.79	V. Lenher.
1047	Medford ...	45.65	18.90	18.00	.86	.29	7.66	1.70	.03	6.55	99.64	28.51	V. Lenher.

2. **RED BURNING SHALES OF LAFAYETTE AND GRANT COUNTIES.** In the southwestern part of the state in the region known as the Mound area, the weathered Maquoketa shale, already referred to (p. 50) yields a bed of tough plastic yellow clay. Although this material does not outcrop at any point, still in the region underlain by it, it can be reached but a few feet below the surface, as the overburden is a thin bed of sandy surface clay. The general section in this area, and the relation of the shale to other beds is indicated in Fig. 5.

One sample of this was taken from a cistern excavation on the farm of W. H. Knebel just east of the Little Mound, near Platteville and tests were made, not only of this weathered Maquoketa shale alone but also of mixtures of the Maquoketa clay with the loess of that region in order to develop if possible any advantages that might be gained by a mixture of them. The tests on these are given below.

Material		Equal parts Maquoketa clay and loess	¾ Maquoketa clay and ¼ loess
Lab. No.	1093	1093-20	1020-93
Soluble salts	.36	.25	.28
Water required	26.4	25.3	29
Slaking	moderately fast	good	good
Plasticity	excellent	excellent	excellent
Grit	almost none	none	little
Air shrinkage	7.2	8.6	7.3
Average tensile strength	156	237	158
Maximum tensile strength	190	298	177

In burning the clay behaved as follows:

Wet-molded bricklets—			
Cone 010:			
Fire shrinkage	.6	0	0
Color	light pink brown	light pink brown	pink brown
Absorption	14.78	14.50	14.37
Cone 05:			
Fire shrinkage	1.7	2	3
Color	red	red	red
Absorption	5.11	8.69	8.13

Cone 03:			
Fire shrinkage........	4	4.3	6
Color	red brown	red brown	red
Absorption	.50	2.93	4.03
Cone 1:			
Fire shrinkage........	vis.	vis.	vis.
Steel hard at cone	08	08	08
Dry-press bricklets—			
Cone 05:			
Fire shrinkage........	....	....	....
Color..................	red	....	....
Absorption.............	....	....	....

1093. This is one of the best-burning brick clays to be found in the state. It gives an excellent red color and a steel hard body even at cone 08 but is not adapted to a very good vitrified body. There is no apparent reason why it should not be used for making drain tile and hollow brick. No prediction can be made regarding its extent and thickness as there are no outcrops of it, but the material is to be searched for in the region around the base of the mounds. The general section that might be expected is as shown in figure 5.

3. Red or Brown-Burning Surface Clays of Varied Origin. Scattered over the central and western parts of the state are many deposits of red or brown-burning surface clays which are used chiefly for the manufacture of common building brick. Those found in western Wisconsin are of the loess type and are all gritty in character. They are worked at LaCrosse, Platteville, Arcadia, Independence, etc. Those found in the eastern and extreme northwestern part of Wisconsin are chiefly lacustrine clays, while the remainder which are especially abundant in the central part are mostly basin-shaped deposits of glacial origin. Among the latter, excellent red-burning ones were noted at Ellsworth, Reedsburg, Milton, Horicon, and Beaver Dam. A most extensive series of beds occurs in northwestern Wisconsin at Menomonie and Tramway.

DETAILED DESCRIPTION OF OCCURRENCES.

Cuba City, Grant Co. Common brick are made from the loess at W. J. Kinlahan's yard. The physical properties of the

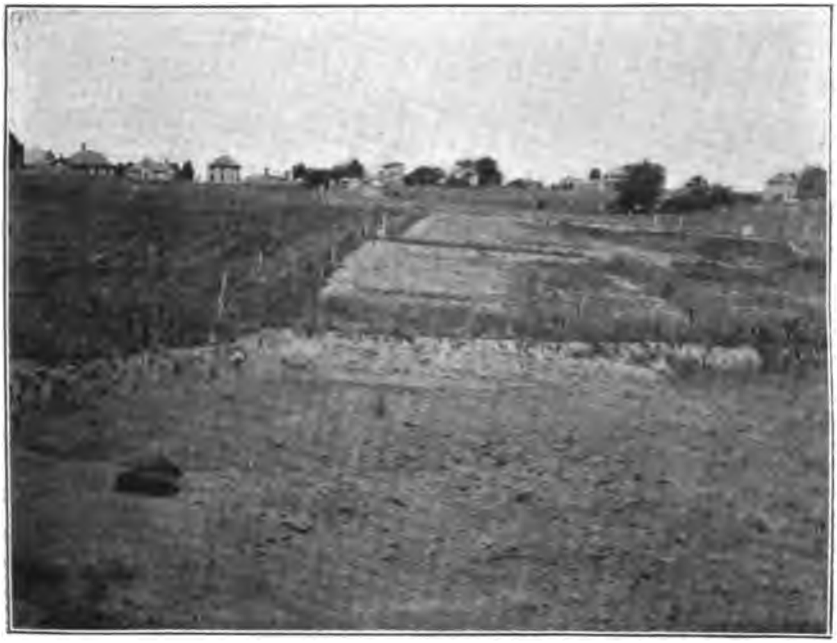


Fig. 1. Clay pit of Grindell Bros., Platteville. This is loess clay, which is dug to but a slight depth, as the underlying "joint" clay is too tough to work.

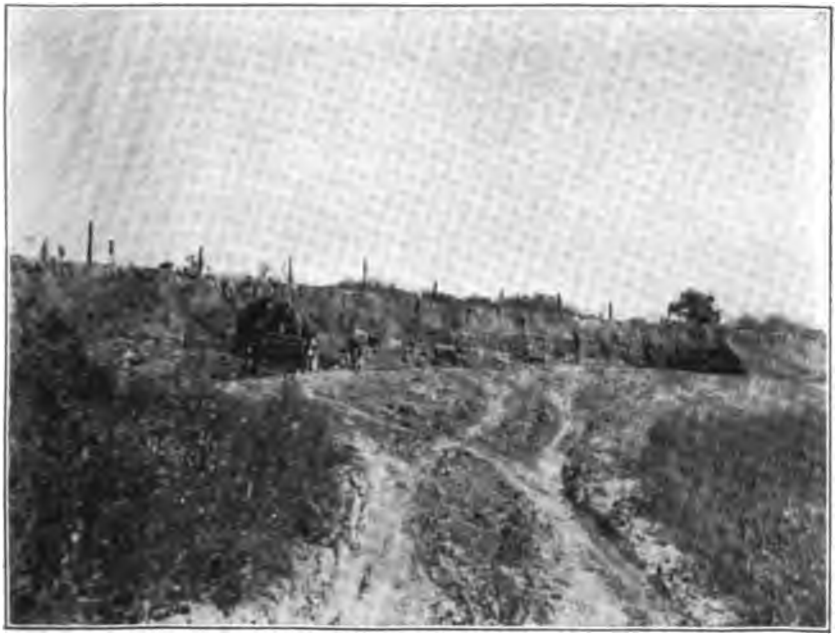


Fig. 2. M. J. Myers' clay bank, La Crosse, Wis. The material is very sandy loess clay, which is used for common brick manufacture.

material (Lab. No. 1022), were, water required, 14; plasticity, moderate; grit, fine; air shrinkage, 8.5.

In burning it behaved as follows:

Wet-molded bricklets:					
Cone	010	05	03	1	2
Fire shrinkage	0	4.	1.3	7	7.5
Color	light red	light red	medium red	dark red	dark brown
Absorption	21.01	19.06	17.59	3.50	2.83

The clay burns steel hard at cone 2.

This clay is capable of giving a good red common brick and is sufficiently hard for brick purposes at 010. It is doubtful if at the time the yard was running this temperature was reached.

Platteville, Grant Co. Two types of clay occur in this locality. One of these is a surface clay or loess which is a finely silty clay, the other the Maquoketa shale which has been described on p. 50. The loess clay is not uniform in character through this section but usually shows a surface clay 18 inches to 2 feet thick (Pl. XIII, Fig. 1) which is loamy or sandy in its character, while below this is a denser somewhat plastic clay which is known locally as *"joint clay"* and is not used for making brick. This latter in places passes into a cherty clay derived from the Galena limestone. A sample of the surface clay (Lab. No. 1020) was tested from the Grindell Brick Co.'s yard at Platteville with the following results: Soluble salts, .33; water required, 30.8; slaking, very fast; plasticity, good; grit, fine; air shrinkage, 8.52; average tensile strength 264 pounds per square inch with a maximum of 334 pounds per square inch. In burning it behaved as follows:

Wet-molded bricklets:				
Cone	010	05	03	1
Fire shrinkage	sl. sw.	.4	3	7.6
Color	light red	red	red brown	dark brown
Absorption	16.13	14.73	8.19	2.70

It burned steel hard at cone 03.

Dry-press bricklets:		
Fire shrinkage	0	8.06
Color	buff brown	red brown
Absorption	20.52	1.48

The dry-press bricks were steel hard at cone 2.

This is a very gritty, porous clay with a granular structure, and burns to a good red color but hard enough for common brick at 010 although it is not steel hard at this point. It is altogether too siliceous for making vitrified brick but could probably be worked on a dry-press machine.

Uses. The material is now being used for common brick which are molded in a soft-mud machine, dried on pallets, and burned in scove kilns, but the temperature reached is not as high as cone 010. The large bricks if dried rapidly show a tendency to crack.

Lancaster, Grant Co. The loess has also been worked at William Barrow's yard on the west edge of this town but only the surface clay has been extracted the clay bank being a shallow excavation not more than 2 or 3 feet in depth. The clay is a reddish-brown plastic material with small mica scales somewhat resembling that at Platteville. At the present yard the foreman stated that they run into a flint rock at a depth of 10 feet. This is probably residual clay containing scattered chert nodules from the Galena limestone.

Fennimore, Grant Co. Red-burning surface loess was formerly used at this town for making common brick. The deposit was shallow and the yard has not been in operation for several years.

Blanchardville, Lafayette Co. A local deposit of alluvial clay (Lab. No. 1024) is worked at this locality for making common brick. The run of the bank which is used had the following properties: Water required, 24.5; plasticity, good; grit, some, coarse; air shrinkage, 6.3.

In burning it behaved as follows:

Wet-molded bricklets:					
Cone	010	05	03	1	2
Fire shrinkage	1	1.7	2.7	5.7	6.7
Color	light red	red	dark red	dark red	dark brown
Absorption	13.97	10.04	7	1.48	1.79

Steel hard at cone 03.

This makes an excellent hard brick at cone 01 but could be burned for common brick at a lower temperature. It is too gritty for the manufacture of vitrified brick.

Monroe, Green Co. Red-burning clays are worked three-fourths of a mile from Monroe at the yard of Kuster, Bowman & Schober. The clay is dug to a depth of 4 to 5 feet and is covered by a black loamy clay about 18 inches in thickness. They claim that if more than 5 feet of clay are used that the brick are of inferior quality. The clay is crumbly in its character and carries scattered pebbles of flint. Underlying this is blue white-burning clay which is not dug on account of the water in it. The properties of the top or red-burning clay (Lab. No. 1017) are: Water, required, 30.5; slaking, fast; plasticity, good; grit, none; air shrinkage, 7.6.

In burning it behaved as follows:

Wet-molded bricklets:					
Cone	010	05	03	1	2
Fire shrinkage	.2	2.6	3.4	7.3	8.3
Color	light red	light red	light red	red	red brown
Absorption	23 87	18.18	17.03	5.05	5

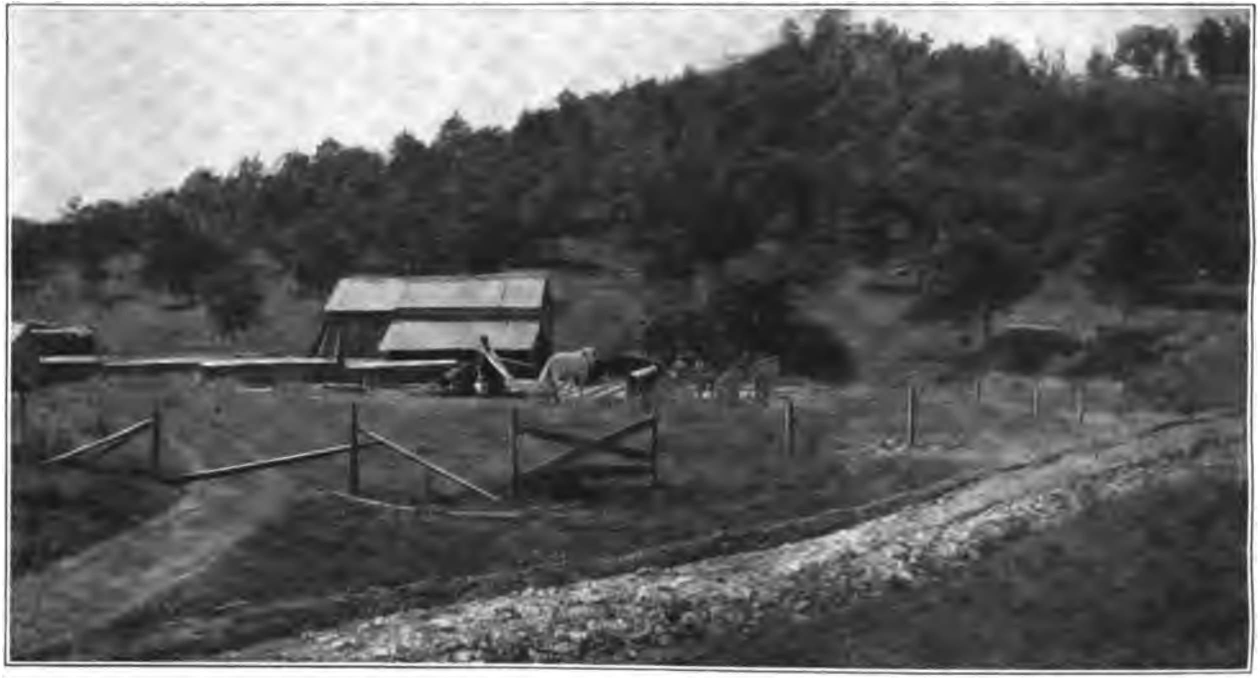
The clay burns steel hard at cone 1. It gives a fairly hard body at 010 and a very hard brick at cone 1, but it is too gritty for making vitrified ware.

Milton, Rock Co. One mile east of town on the road to Lima on the property of L. B. Borden on the south side of the road, there is a deposit of clay not more than 500 feet from the railroad which according to Mr. Borden's statement is 12 feet in thickness and is overlain by 2 to 3 feet of gravel. The material is a tough plastic clay which is not being worked but has been successfully experimented with at a small pottery near Edgerton.

It burns to a fairly bright red color and a vitrified body but if large pieces are burned to vitrification they show a slight tendency to crack. On the north side of the railroad there is another clay deposit which lies in a similar position to that of Borden's, but is on the property of Mr. Goodrich. Although the two deposits are not more than 1,000 feet apart they are greatly different in their character as can be seen from the following tests.

Material	Borden clay	Goodrich clay
Laboratory No.	1012	1013
Soluble salts	.32	.41
Water required	20.9	34.1
Slaking	moderately fast	fast
Plasticity	fair	high
Grit	some, fine	much, fine
Air shrinkage	7.7	3.38
Average tensile strength	312	158
Maximum tensile strength	370	184
Wet-molded bricklets—		
Cone 010:		
Fire shrinkage	sl. sw.	sl. sw.
Color	light brown	cream
Absorption	13.59	54.34
Cone 05:		
Fire shrinkage	.3	
Color	light red	
Absorption	10.02	
Cone 03:		
Fire shrinkage	1.8	sl. sw.
Color	light brown	gray buff
Absorption	5.41	48.40
Cone 1:		
Fire shrinkage	.5	sl. sw.
Color	dark brown	gray buff
Absorption	1.39 vit.	36.47
Dry-press bricklets—		
Cone 05:		
Fire shrinkage	0	
Color	buff brown	
Absorption	17.83	
Cone 2:		
Fire shrinkage	8	
Color	red brown	
Absorption	.70	

The clay burned steel hard at 05 when wet-molded.



Brick yard and clay pit at Richland Center. This plant represents well the type of small yard in operation at many points.

The chemical composition of the Borden clay is:

Silica (SiO_2)	71.56
Alumina (Al_2O_3)	11.15
Ferric oxide (Fe_2O_3)	3.73
Lime (CaO)	1.70
Magnesia (MgO)	.96
Potash (K_2O)	2.41
Soda (Na_2O)	1.28
Loss on ignition	6.33
Total	99.12
Total fluxes	10.08

It is hardly necessary to point out the differences between these two clays as they are so evident. The Borden clay burns to a good color and good body, while the other is so open burning and gritty that it is of little value.

Janesville, Rock Co. There is one brick yard at this locality namely that of the Janesville Red-Brick Co. which for unknown reasons has not been in operation for several years. The bank is a long shallow excavation showing a fine-grained cross-bedded sand and clay of which at least 6 feet are exposed and which is very lean. The overburden consists of 3 to 6 feet of gravelly clay and sand. On top of this in places there are pockets of red clay, which seems to be the only material on the property that could be satisfactorily used for making bricks. This burns to an excellent red color and would even make a good dry-press brick or tile but the deposit is rather shallow and a large area would have to be worked over in order to get sufficient material for a brick plant.

Richland Center, Rock Co. William Bliesner is working a deposit of sandy surface clay of possibly modified residual material at the base of the hill west of town. (Pl. XIV.) The material is a gritty red-burning plastic clay which tends to crack badly in air drying and to prevent this salt is mixed with the clay in the proportion of one gallon salt to 700 brick. The material is tempered in a pug mill, molded by hand, dried on an open yard and burned in scove kilns.

Viola, Richland Co. Another deposit of red-burning surface clay (Lab. No. 1025) is worked at Viola at the yard of Pahl and Sherry. Its physical properties were as follows: Water required, 17.6; plasticity, good; grit, some, coarse; air shrinkage, 5.94. In burning it behaved as follows:

Wet-molded bricklets:					
Cone	010	05	03	1	2
Fire shrinkage	.4	2	4	7.6	8
Color	very light red	red	red	dark red	red brown
Absorption	17.68	13.76	7.74	1.58	1.83

The clay burns steel hard at 03 but gives a good brick body even at cone 010.

Mazomanie, Dane Co. A deposit of clay 12 feet deep (Lab. No. 1182) occurs on the property of Mr. H. H. Willard. It works up with 17.6 per cent of water to a mass of fair plasticity but considerable fine grit whose air shinkage is 7.4. In burning it behaved as follows:

Wet-molded bricklets:				
Cone	010	05	03	1
Fire shrinkage	sl. sw.	sl. sw.	2.7	4.6
Color	yellow brown	dark buff	red brown	red brown
Absorption	14.03	14.10	7.2	3.15

Burns steel hard at cone 03.

This is a good red-burning common-brick clay which could probably be burned at as low a cone as 05. At cone 03 the clay deepens too much. It could probably be molded dry press.

Madison, Dane Co. Red-burning clay is found at Stephens' yard, but since it occurs in the same bank with the cream-burning clay, it has, to facilitate comparison, been described on an earlier page.

Reedsburg, Sauk Co. This town lies within the driftless area. Only one yard is in operation here, viz., that of Halbersleben one mile west of the city. The deposit of red surface clay (Lab. No. 1123) is worked to a depth of 3 feet, after first stripping off the black surface loam. It works up with 22 per cent of water to a mass of good plasticity and containing some coarse grit. Its air shrinkage is 7 per cent, and in burning it behaved as follows:

Cone	010	05	03	1
Fire shrinkage	.3	4	1	6.3
Color	light red	buff	light red	dark red
Absorption	14.20	13.19	12.92	1.98

It burned steel hard at cone 1.

Uses. This is one of the best red-burning clays that was tested from the state and for pressed brick it would probably work just as well as the clay dug at Menomonie. Up to the present time no attempts have been made to use it for this purpose.

A more sandy clay is used at a similar yard at Plain, Sauk Co. This clay (Lab. No. 1102) works up with 22 per cent of water to a mass of good plasticity and some grit, whose air shrinkage is 4.3 per cent. In burning it behaved as follows:

Wet-molded bricklets:					
Cone	010	05	03	1	2
Fire shrinkage	0	0	.7	5	7.7
Color	light red	red	red	dark red	brown
Absorption	16.65	16.27	15.80	5	1.68

The clay burns steel hard at cone 2. It is a very sandy brick clay which burns to a good red color and gives a fairly hard brick even at cone 010. The clay is employed for the manufacture of common brick and in burning it is doubtful whether a temperature of 010 is reached.

Beaver Dam, Dodge Co. A red-burning estuarine clay is being worked one mile north of this town and is among the best red-burning clays that were seen in the state. The deposit has been worked to a depth of 3 feet and is overlain by a thin layer of soil. The sample (Lab. No. 1059) worked up with 26.4 water to a mass of fair plasticity, and with considerable fine grit whose air shrinkage was 8.5 per cent.

In burning it behaved as follows:

Wet-molded bricklets:				
Cone	010	05	03	1
Fire shrinkage	0	1.3	4.7	8.4
Color	light red	red	dark red brown	red brown
Absorption	14.49	12.31	4.87	1.29

When air dried the clay formed a good hard body. It burned steel hard at cone 010. It is doubtful whether it would stand much more than cone 1 as it shows signs of becoming viscous at that point.

Uses. The clay has been used by the Beaver Dam Brick Co. for the manufacture of common brick, but the plant was not in operation at the time it was visited.

Horicon, Dodge Co. The red-burning clays at the locality are so intimately associated with the cream burning ones, that the tests on them are given under that head.

Schleisingerville, Washington, Co. The red-burning clays from here are discussed with the cream-burning ones, for the same reasons mentioned under Horicon.

Iron Ridge, Dodge Co. Underlying the Clinton ore at this locality is a bed of clay at least 18 feet thick. It is divisible into an upper clay 6 feet in thickness (Lab. No. 1027) which immediately underlies the iron ore and the lower clay 12 feet thick below the upper clay. Neither of these are worked nor have they ever been used for the manufacture of brick so that it is of interest to determine their physical properties which were as follows:

Material	Upper clay	Lower clay
Laboratory number	1027	1172
Water required	18.7	17.6
Slakes	moderately fast	....
Plasticity	excellent	high
Grit	....	low
Air shrinkage	4.6	4.7
Average tensile strength	75.3	62.
Maximum tensile strength	87.0	80.
Wet-molded bricklets—		
Cone 010:		
Fire shrinkage	sl. sw.	....
Color	light brown	....
Absorption	23.51	....
Cone 05:		
Fire shrinkage	sl. sw.	....
Color	light brown	....
Absorption	22.34	....
Cone 03:		
Fire shrinkage	sl. sw.	sl. sw.
Color	brown	red brown
Absorption	20	25.74

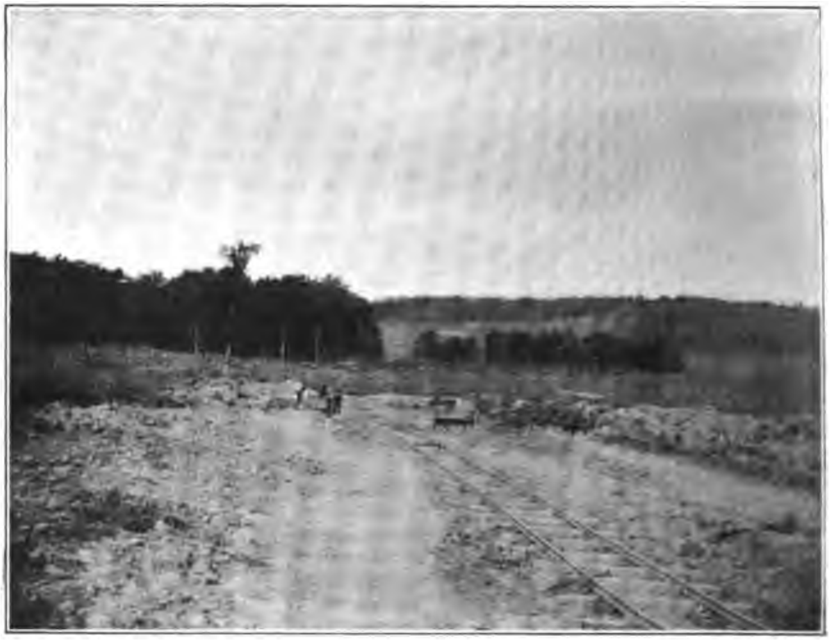


Fig. 1. Clay pit at Thierault's yard, Chippewa Falls. This shows the shallow character of most of the excavations in glacial clays.

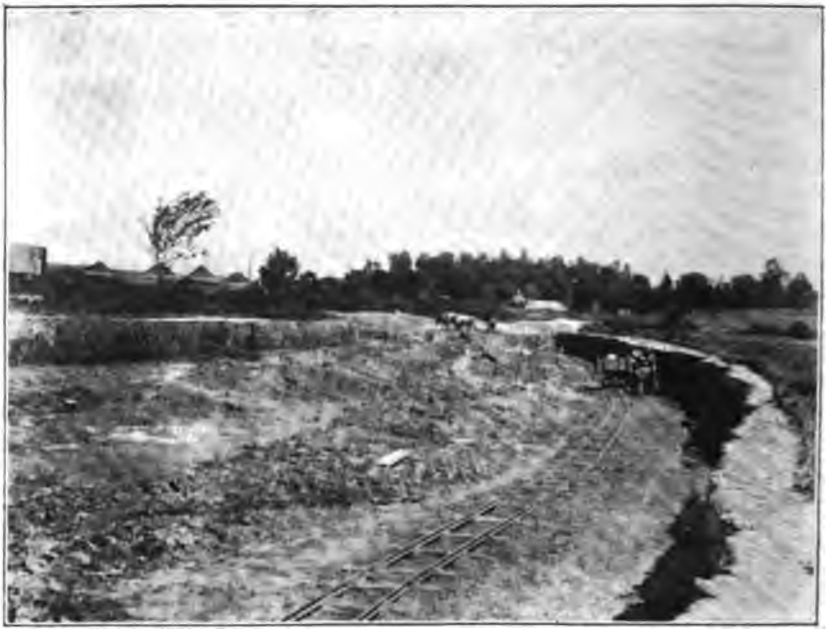


Fig. 2. Clay bank of Hydraulic Pressed Brick Co., Menomonie. A loamy clay of loessoid type and red-burning.

Cone 1:		
Fire shrinkage	sl. sw.	....
Color	pink buff	brown
Absorption	18.54	25.60

Chemical composition.

Silica (SiO_2)	30.90
Alumina (Al_2O_3)	7.96
Ferric oxide (Fe_2O_3)	9.13
Lime (CaO)	17.30
Magnesia (MgO)	4.80
Potash (K_2O)	3.75
Soda (Na_2O)	.37
Titanic acid (TiO_2)	.09
Loss on ignition	25.30
Total	99.60
Total fluxes	35.35

Of these two clays the upper clay is by far the better While it burns to a good hard brick still it is not a very dense one. It stands fast drying fairly well without cracking. The lower clay gives a brick with a good ring but lacks density. The upper clay could probably be worked in connection with the iron ore.

The analysis given above would suggest a buff-burning clay, but the high iron percentage probably prevents this.

Viroqua, Vernon Co. This locality lies in the region covered by the loess and the clays employed are quite silty in their character but nevertheless burn to a denser body at a low cone than many of the cream-burning calcareous clays found in the eastern part of the state. Two samples were tested from here. One of these (Lab. No. 1026), represents the brick mixture used at Pahl's yard which is the combination of the clay and overlying sand, while the other is a brick mixture from S. Foster's yard (Lab. No. 1079). Their properties are given below.

Lab. No.	1026	1079
Water required	23.1	20.9
Slaking	fast	fast
Grit	much, fine	much, fine
Air shrinkage	5.6	3.4
Average tensile strength	228	....
Maximum tensile strength	254	....

Wet-molded bricklets—		
Cone 010:		
Fire shrinkage	0	sl. sw.
Color	yellow brown	light yellow brown
Absorption	16.09	20.98
Cone 05:		
Fire shrinkage	....	sl. sw.
Color	....	brownish yellow
Absorption	....	20.08
Cone 03:		
Fire shrinkage	4.7	0
Color	red brown	light brown
Absorption	8.01	18.32
Cone 1:		
Fire shrinkage	6.6	9
Color	red brown	brown
Absorption	2.78	1.71
Cone 3:		
Fire shrinkage	vis. begun	....

The first of these burns steel hard at cone 03 and makes a good reddish brick even at cone 010 but the color deepens at 03 and considerably at cone 1. There is no apparent reason why this clay should not work well for dry-press bricks.

The second clay, 1079, does not burn steel hard until cone 1, and shows the effect of the admixture of sand to clay. It gives a hard but by no means a dense brick and shows a high increase in shrinkage at cone 1. In order to get the best color it should not be burned above cone 03. Both samples are too gritty to yield a vitrified body.

The siliceous character of the clays is also indicated by the two following analyses given by Buckley.[*]

	I	II
Silica (SiO_2)	74.71	78.26
Alumina (Al_2O_3)	12.60	11.41
Ferric oxide (Fe_2O_3)	2.80	1.80
Lime (CaO)	.70	1.00
Magnesia (MgO)	.55	.68
Potash (K_2O)	2.18	1.88
Soda (Na_2O)	1.14	1.28
Titanic acid (TiO_2)	.55	.45
Ignition	5.30	3.12
Total	100.53	99.88

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[*] Op. cit., p. 274.

Berlin, Green Lake Co. The lacustrine clays at this locality were formerly worked by C. S. Morris but the plant has been temporarily abandoned owing to the difficulty of draining the deposit. While in operation the clay was used for making a stiff-mud side-cut brick, and these when properly burned had an excellent ring and showed a high crushing strength.

Fond du Lac, Fond du Lac Co. The estuarine clays have been opened up at this locality for the manufacture of common brick and are worked at the yard of H. G. Hass and Bro. The clay is worked only to a depth of three to four feet, although it runs much deeper, but the lower layers contain too many limestone pebbles.

The properties of the run of the bank (Lab. No. 1043) were: soluble salts, .50; water required, 25.3; slaking, fast; plasticity high; grit, some, fine; air shrinkage 7.4. Average tensile strength 286.6; maximum tensile strength 356.5 pounds per square inch. In burning it behaved as follows:

Wet-molded bricklets:					
Cone	01	05	03	1	2
Fire shrinkage	.3	.3	1.4	3.6	4.4
Color	buff red	light red	brown	brown	dark gray
Absorption	20	18.15	13.71	5.66	2.56

Dry-pressed bricklets:-		
Fire shrinkage	0	1.33
Color	light brown	speckled gray
Absorption	27.81	11.61

The clay gives a good hard body even at 010 and if burned to 03 the iron shows a speckled appearance which continued up to cone 2, at which cone the dark specks of the clay showed signs of fusing. In order to make dry-press brick the clay should be burned at least at cone 03.

La Crosse, La Crosse Co. There are three yards in the vicinity of La Crosse engaged in the manufacture of common brick and in all of them the material used is a very sandy stratified clay of the loess type, which is found underlying the low hills around La Crosse and extending back to the base of the limestone bluffs. In all of the banks examined there seems to be more or less lack of uniformity in the character of the material, sandy streaks sometimes predominating to the exclusion of the clay and all grades being found from fine silty clay to coarse clay sand. As a rule the run of the bank is used.

In order to point out the properties of this material one sample was taken from the bank of Schnell Bros. representing the run of the bank or the brick mixture. (Lab. No. 1109.) Its properties were as follows: Soluble salts, .15; water required, 22; slaking, fast; plasticity, lean; grit, much, coarse; air shrinkage, 3.6; average tensile strength 226.8 pounds per square inch with a maximum of 252 pounds per square inch. In burning it behaved as follows:

Wet-molded bricklets:				
Cone	010	05	03	1
Fire shrinkage	sl. sw.	sl. sw.	1	1
Color	brownish yellow	light red	red brown	dark brown
Absorption	18.59	18.71	16.05	8.38

The clay burns steel hard at cone 1 and gives a common brick of good color even at a low cone, but the absorption as can be seen from the test is rather high, although not excessive unless the clay is burned to cone 1 and at that cone the color is too deep to suit most people.

Uses. The clays around LaCrosse are worked by Schnell Bros., D. Mader, and M. J. Myers. The product at all the yards is common brick and the clay is molded in horse-power machines, dried on open yards, and burned in scove kilns.

Tomah, Monroe Co. In the clay pit at this locality the section observed was:

Red top clay	5 ft.
Blue clay	14 ft.

Of the latter only 5 feet were exposed. The clay contains some scattered angular stones and also streaks of limonite and the general run of it is quite silty. This clay (Lab. No. 1122) has the following properties: water required, 13.2; slaking, moderately fast; plasticity, low; grit, some, fine; air shrinkage, 3.8. In burning it behaved as follows:

Wet-molded bricklets:				
Cone	010	05	03	1-2
Fire shrinkage	sl. sw.	0	1	4.3
Color	brownish yellow	red brown	red brown	brown
Absorption	15.75	15.52	13.91	5.58

The clay does not burn steel hard until cone 1 and gives a porous though even-grained body. It burns to a fair color but lacks a good ring and in order to get good results should be mixed with a more plastic clay.

Independence, Trempeleau Co. The loess clays are worked here at the yard of J. Hertzfeldt in whose bank the section shows:

Silty loam	1 ft.
Fine yellow sandy clay	¾ ft.

No sample was tested from this locality but the clay burns to a red although somewhat porous brick.

Arcadia, Trempeleau Co. Here again the loess clays are used and a physical test made on the sample from the yard of E. and A. Pahl shows that they resemble those dug at La Crosse. The tests on the sample representing the run of the bank (Lab. No. 1077) were as follows: water required, 24; slaking, fast; plasticity, good; grit much, fine; air shrinkage, 5.7. In burning it behaved as follows:

Wet-molded bricklets:					
Cone	010	05	03	1	2
Fire shrinkage	.7	.3	1.7	5.7	5.7
Color	very light red	red	red	dark red	dark brown
Absorption	16.26	15.30	12.15	2.95	3.09

The clay burns steel hard at cone 1. It is a very sandy brick clay showing scattered mica scales and does not give a good hard brick below 03, although the color of it is good. Above cone 03, the color deepens rapidly and the clay burns to a very hard but not vitrified body at cone 1–2. The siliceous character of this clay is well brought out by the following analysis:

Silica (SiO_2)	73.08
Alumina (Al_2O_3)	11.56
Ferric oxide (Fe_2O_3)	4.11
Lime (CaO)	.84
Magnesia (MgO)	.52
Potash (K_2O)	2.31
Soda (Na_2O)	2.75
Titanic acid (TiO_2)	.09
Loss on ignition	5.36
Total	100.62
Total fluxes	10.53

Uses. The clay is employed for the manufacture of common brick at Pahl's yard. It is prepared in a soak pit, molded in a horse-power machine, dried on hacks on the yard, and burned in scove kilns.

Marshfield, Wood Co. At the works of the Central Wisconsin Pressed-Brick Co. 3 miles north of town there is an extensive deposit of surface clay probably of glacial origin, underlying a swamp tract. At the time of our visit the section showed

1.	Soil	6 inches
2.	Gray clay	1 to 2 ft.
3.	Yellow sandy clay	4 ft.
4.	Black siliceous clay	1 ft.
5.	Sandy gravel	8 in.
6.	White gritty clay	4 to 5 ft.
7.	Blue clay	30 ft.

Numbers 2, 3, 4 and 5, are mixed together for brick manufacture. The section evidently varies from point to point and the clay noted in the face of the bank six months later might differ entirely from the clay given above. The pit is not more than 6 feet deep and consequently the blue bottom clay is not exposed. The statement was made that the latter alone burned to a very dense body and consequently was well adapted for the manufacture of pottery, and in order to test this point a sample was taken of the run of the bank used for making brick exclusive of the blue clay and the second sample representing the blue clay alone. The properties were as follows:

Material	Brick mixture	Lower blue clay
Laboratory No.	1170	1169
Soluble salts	.19	.18
Water required	17.6	22
Slaking	fast	slow
Plasticity	low	good
Grit	much, coarse	some, fine
Air shrinkage	5	4.8
Average tensile strength	327	
Maximum tensile strength	393	
Wet-molded bricklets—		
Cone 010:		
Fire shrinkage	sl. sw.	sl. sw.
Color	yellow brown	yellow brown
Absorption	11.23	14.51
Cone 05:		
Fire shrinkage	0	.3
Color	yellow brown	yellow brown
Absorption	11.13	13.51
Cone 03:		
Fire shrinkage	1	
Color	red brown	
Absorption	8.55	
Cone 1:		
Fire shrinkage	4.3	5.3
Color	brown	red brown
Absorption	3.16	3.86
Steel hard at cone	1	1
Dry-press bricklets—		
Cone 1:		
Fire shrinkage	2	4.33
Color	red brown	brown
Absorption	11.11	3.20

The brick mixture gives a very fair color in burning but the bricks unless burned hard lack a good ring. The lower blue clay burns to a good color up to 05 but deepens considerably above this and although very plastic it does not burn to a sufficiently dense body and is not sufficiently fine-grained to make a good pottery clay. It would probably fuse at cone 3. The chemical composition of the blue clay is:

Silica (SiO_2)	72.60
Alumina (Al_2O_3)	12.16
Ferric oxide (Fe_2O_3)	5.66
Lime (CaO)	1.34
Magnesia (MgO)	.08
Potash (K_2O)	2.47
Soda (Na_2O)	1.44
Loss on ignition	4.07
Total	99.86
Total fluxes	10.99

Uses. The clay at the present time is employed entirely for making common brick. It is prepared in a pug mill and molded in a soft-mud machine. Drying is done on pallets and burning in Dutch kilns. The color of the brick is considerably improved by the use of hematite in the molding sand.

Hewitt, Wood Co. A deposit of red-burning alluvial clay is known to occur along Mill Creek one mile south of the Wisconsin Central Railroad station of Hewitt, and from the samples taken in an eight inch boring by Mr. F. H. Merrell of Portage City it (Lab. No. 1085) was found to have the following qualities: Soluble salts .40; water required, 22; slaking, fast; plasticity, medium; grit, fine; air shrinkage, 4.46; average tensile strength, 249 pounds per square inch with a maximum of 274 pounds per square inch. In burning it behaved as follows:

Wet-molded bricklets:					
Cone	010	05	03	1	2
Fire shrinkage	0	.3	2	6	5
Color	red	medium red	dark red	dark red	dark brown
Absorption	14.10	13.10	5.94	1.57	1.60
Steel hard at cone	03	....	....	....	....

Dry-press bricklets:		
Fire shrinkage	0	7.33
Color	buff bro'n	red brown
Absorption	16.64	4.92

Its chemical composition as analyzed by A. S. Mitchell of Milwaukee was:

Silica (SiO_2)	75.24
Alumina (Al_2O_3)	12.21
Ferric oxide (Fe_2O_3)	3.89
Lime (CaO)	1.74
Magnesia (MgO)	1.01
Alkalies by difference	2.56
Loss on ignition	3.35
Total	100.00

This is a good red-burning clay of low fire shrinkage, as might be expected from the high silica contents shown in the analysis and yet in spite of its siliceous character it burns to a fairly dense brick of good red color. In burning, however, the brightest colors are obtained at cone 05, or lower, and above this cone the color deepens considerably. It would no doubt work well by either dry-press and wet-molded methods.

Clintonville, Waupaca Co. The country around this town is underlain by shallow deposits of lacustrine clay but the only one that is opened up is about a half mile due southwest of the town, on the property of Alf and Son. The material here is laminated, plastic clay of reddish-brown color and underlain in places by sandy clay or gravel. Its exact depth is not known but it averages about 6 feet. The cream-burning under clay is absent at this locality. No one deposit of clay here is probably extensive enough for a large plant but there is sufficient to start a brick yard of medium size. The clay is very gritty and hence shows a small shrinkage in burning and drying and even in a distance of 50 feet exhibits considerable variation in its character with a corresponding difference in air and fire shrinkage. As an example of this we may take two samples taken from different parts of the bank but at the same level. Their properties were as follows:

Material	S.W. end of bank	N.E. end of bank
Lab. No.	1126	1144
Water required	23.1	19.8
Plasticity	high	good
Grit	considerable	much
Air shrinkage	6.2	3.4

Wet-molded bricklets—		
Cone 010:		
Fire shrinkage	0	0
Color	brownish yellow	yellow brown
Absorption	15.66	16.02
Cone 05:		
Fire shrinkage	2.3	0
Color	red brown	brown buff
Absorption	11.37	16.49
Cone 03:		
Fire shrinkage	3	0
Color	dark red brown	brown buff
Absorption	3.23	14.88
Cone 1:		
Fire shrinkage		4.6
Color		green brown
Absorption		4.76
Steel hard at cone	03	1

Uses. The clay is now being used for the manufacture of common brick by the soft-mud process. The bricks are dried on an open yard and burned in scove kilns at a temperature somewhat lower than cone 010.

Waupaca, Waupaca Co. C. Gminer is working a small deposit of alluvial clay about three miles southeast of town. The clay lies in a hollow along the south branch of the Little Wolf river and burns to a reddish-brown color.

Green Bay, Brown Co. In addition to the cream-burning clays occurring at this locality there are a number of red-burning clays which are usually found immediately underlying the surface and sometimes overlying the calcareous cream-burning deposits. Among the yards at which clays of this type are worked at are those of A. H. Eiserman located three miles east of Hagermeister's Brewery at the forks of the Manitowoc road; Douchateau Bros. on Dutchman's Creek, two miles south of Green Bay; and the Reformatory Brick Yard on the east side of the river three miles south of Green Bay. At Douchateau's yard both red and white-burning clay are found, the section involving:

Loam	1 ft.
Red-burning clay	3 ft.
White-burning clay	Thickness unknown

The red and white-burning clays are mixed together for making a red brick while the white clay alone is used for tile. At Eiserman's yard the section shows 1 foot of mixed layers of clay and sand, underlain by iron-streaked red-burning clay whose thickness is unknown.

The deposit is excavated to a depth of 3 feet and the run of the bank is used. The properties of this (Lab. No. 1082) are as follows: Water required, 19.8; plasticity, good; grit, some, coarse; air shrinkage, 7.1. In burning it behaved as follows:

Wet-molded bricklets:				
Cone	010	05	03	1
Fire shrinkage	1	.4	3	vis.
Color	red brown	light pink	light red brown	greenish brown
Absorption	14.55	14.60	6.81	1.11

This clay gives a fairly hard body but the bricklets lacked a good ring. Its fusion point is quite low.

At the Reformatory yard the section shows:

Soil	6 in.
Sandy loam	6 in.
Brownish clay	to a depth of six in.
Cream-burning clay.	

The red-burning clay overlies the cream-burning material and forms the greater part of the brick mixture. The cream-burning clay is, however, much tougher and does not break up as easily in the pug mill as the red, consequently lumps are to be seen scattered through the brick. At Smith Bros.' yard the physical properties of the red-burning clay (Lab. No. 1091) are: Water required, 20.9; slaking, fast; plasticity, fine; grit, much, coarse; air shrinkage, 7.1.

In burning it behaved as follows:

Wet-molded bricklets:				
Cone	010	05	03	1
Fire shrinkage	0	.3	1.4	vis.
Color	light red brown	pinkish	light brown	greenish gray.
Absorption	25 45	15.46	6.94	....

Steel hard at cone 03.

This is a gritty porous clay but makes a very good common brick.

Uses. The material is now used for making common brick which are molded either on a soft-mud or a stiff-mud machine, dried on pallets, and burned in scove kilns. About 20 per cent of sand taken from a neighboring bank is mixed with the clay.

Spring Valley, Pierce Co. A small deposit of very sandy clay is used for brick at this town the plant being operated by F. Lowater. The brick are soft-mud and burned in scove kilns.

River Falls, Pierce Co. The loess clays have been opened up here at the yard of the River Falls Brick Co. They are used for making soft-mud brick.

At *Ellsworth* in the same county a deposit of flood-plain clay has been opened up which shows black loam underlain by 5 feet sandy clay. This material (Lab. No. 1100) is used in the proportion of ¼ surface loam and ¾ clay. The mixture which slakes moderately fast works up with 19.8 water to a mass of low plasticity and containing much grit whose air shrinkage is 3.1. In burning it behaved as follows:

Wet-molded bricklets:			
Cone	010	05	
Fire shrinkage	sl. sw	1.3	3.41
Color	yellow brown	red brown	red brown
Absorption	15.10	11.07	5.93

It became steel hard at cone 03.

The clay burns to a good red color but even at 05 does not give a hard brick.

Uses. It is employed for making soft-mud brick which are dried on pallets and burned in scove kilns.

Durand, Pepin Co. A clay bank is located on a bluff one-half mile west of J. T. Dorchester's yard and consists of an average of 3 feet of sandy yellow clay underlain by a more shaly clay which is called fire clay. The brick clay (Lab. No. 1040) has the following properties; soluble salts, .34; water required, 18.7; plasticity, low; grit, much; air shrinkage, 4.8; average tensile strength, 242.8 pounds per square inch; maximum tensile strength 263 pounds per square inch. In burning it behaved as follows:

Wet-molded bricklets:					
Cone	010	05	03	1	2
Fire shrinkage	sl. sw.	.6	4.4	5	6.3
Color	light red	light red	dark red	dark red	dark brown
Absorption	14.16	10.53	7.36	3.43	1.54
Steel hard at cone 05.					

Dry-press bricklets:		
Cone	05	1-2
Fire shrinkage	0	6
Color	buff brown	brown
Absorption	16.50	7.71

The clay although very gritty will not stand rapid drying. It contains small angular fragments of apparently decomposed sandstone and while it gives a good hard brick it is too gritty to make a vitrified one. It is also rather sandy for dry-press brick and if used for this purpose should be burned at not less than cone 03.

The fire clay (Lab. No. 1141) so-called, gave the following physical properties: Water required, 15; slaking, fast; plasticity, low; grit, much; air shrinkage, 9. In burning it behaved as follows:

Wet-molded bricklets:						
Cone	010	05	03	1	3	5
Fire shrinkage	sl. sw.	sl. sw.	sl. sw.	sl. sw.	sl. sw.	not yet vit.
Color	gray buff	gray buff	gray buff	....	gray buff	....
Absorption	27.44	29.78	29.90	28.67	27.51	quite hard

This is a very open-burning clay and probably of not much value for structural work, but is more refractory than many of the other clays tested; still it is not to be regarded by any means as a fire clay for it contains a high percentage of fusible impurities as seen by the following analysis:

Silica (SiO_2)	46.42
Alumina (Al_2O_3)	7.79
Ferric oxide Fe_2O_3)	3.09
Lime (CaO)	12.16
Magnesia (MgO)	7.58
Potash (K_2O)	4.94
Soda (Na_2O)	.45
Titanic acid (TiO_2)	.13
Loss on ignition	7.96
Total	100.52
Total fluxes	28.22

Neillsville, Clark Co. A clay deposit has been developed here at the yard of A. A. Schoengarth and the clay is known to overlie an area of 60 acres to a depth of 6 feet. The siliceous character of the clay (Lab. No. 1173) shows up well in the following test of its physical properties. Water required, 22; plasticity, fair; grit, much, fine; air shrinkage, 4.2. In burning it behaved as follows:

Wet-molded bricklets:				
Cone	010	05	03	1
Fire shrinkage	sl. sw.	0	.7	2
Color	yellow brown	yellow brown	light red brown	light red brown
Absorption	17.08	16.78	14.54	11.78

Dry-press bricklets:	
Fire shrinkage	3
Color	red brown
Absorption	10.60

Although this clay is pretty gritty it would no doubt work in a dry-press machine, and burns to a fair color.

Uses. At the present time the material is used simply for the manufacture of soft-mud brick which are dried on pallets and burned in scove kilns. There seems to be little cracking in the burning. The brick could be improved if more plastic clay could be found to mix with that now used.

Athens, Marathon Co. There are scattered deposits of glacial clays around this town and one of these was opened up in the summer of 1904 by the Athens Brick and Tile Company, at a point one and a half miles east of town on the road to Edgar.

At the time of the writer's visit the pit whch had been made was quite small and showed a tough red, stony, glacial clay which rested on bed rock, the latter being encountered at a depth of from 7 to 8 feet. The location is a rather undesirable one and it is possible that by intelligent prospecting a deposit could have been found which contained fewer stones. The clay itself is very tough and large bricks tested showed that it had a tendency to crack in air drying, especially if the latter was carried on very rapidly. This can be prevented to some extent by adding some of the top soil to the clay. The properties of the clay (Lab. No. 1049) were as follows: Water required, 19.8; plasticity, good; grit, much, coarse; air shrinkage, 5.7. In burning it behaved as follows:

Wet-molded bricklets:				
Cone	010	06	03	1
Fire shrinkage	sl. sw.	1.4	1.4	5
Color	light red	dark red	medium red	dark red
Absorption	12.27	7.91	8.94	1.30

The clay burns steel hard at cone 05 at which point it is not far from viscous. When freed from the stones and mixed with the soil it makes a very fair red-burning brick mixture and is being used for the manufacture of soft-mud brick.

Edgar, Marathon Co. There are two yards here, one of which has suspended operation for several years, while the other, T. Hill's yard, located on the southern edge of town with a bed of clay about 75 feet further south is in active operation. The clay deposit which underlies a swamp shows the following section:

Red clay	3 ft.
Coarse grained sand	6 to 12 ft.
Dark blue clay	depth unknown

For making bricks the run of the bank exclusive of the blue clay is used. The blue clay is exceedingly plastic, rather dense and on sight would appear to be adapted to the manufacture of drain tile or perhaps even common red earthenware, but the physical test and chemical analysis made on it indicate how deceptive it is in appearance. Its physical properties (Lab. No. 1050) are as follows: Water required, 26.4; slaking, slow; plasticity, high; grit, considerable; air shrinkage, 9.2; average te sile strength aobut 200 pounds per square inch. In burning behaved as follows:

Wet-molded bricklets:				
Cone	010	05	03	1
Fire shrinkage	0	sl. sw.	2 3	2.9
Color	light red	red	red	red brow
Absorption	11.83	9.20	7.44	2.56
Steel hard at cone 03.				

Chemical composition.

Silica (SiO_2)	64.46
Alumina (Al_2O_3)	8.73
Ferric oxide (Fe_2O_3)	5.40
Lime (CaO)	7.32
Magnesia (MgO)	.16
Potash (K_2O)	1.45
Soda (Na_2O)	1.44
Titanic acid (TiO_2)	.07
Loss on ignition	11.10
Total	100.07
Total fluxes	15.77

The clay authough red-burning, contains considerable organic matter and has to be fired very slowly in order to prevent swelling. It is also too gritty to be used for drain tile or common earthenware.

Wausau, Marathon Co. Surrounding this town there are a number of shallow surface deposits of rather silty clay which are worked by several small yards for the manufacture of hand-molded common brick. The material is quite silty and is burned at a very low temperature. The character of this surface clay can be seen from the following test (Lab. No. 1110) made on a sample from Garske's yard north of Wausau. Water required, 17.6; slaking, slow; plasticity, fair; grit, much, coarse; air shrinkage, 3.9. In burning it behaved as follows:

Wet-molded bricklets:			
Cone	010	05	1
Fire shrinkage	sl. sw.	0	3.3
Color	yellow brown	yellow brown	red brown
Absorption	13.65	10.90	5.58
Steel hard at cone 1.			

The material makes a very fair common brick, although it is not very dense-burning, but still it is much more so than the loess clays around La Crosse. A thicker deposit occurs on the property of H. Gerbsch located in the N. E. ¼ of the S. W. ¼ section 29, range 7, and the section of the deposit shows:

Sand	8 ft.
Silty clay	18 ft.

The properties of this material (Lab. No. 1006) are: Water required, 26.4 soluble salts, .31; slaking, slowly; plasticity, high; grit, some, coarse; air shrinkage, 7.7; average tensile strength 299 pounds per square inch; maximum 386 pounds per square inch. The material will not stand rapid air drying. In burning it behaved as follows:

Wet-molded bricklets:				
Cone	010	05	03	2
Fire shrinkage	0	1	5	7.4
Color	light red	medium red	light brown	brown
Absorption	14.54	12.40	4.23	.77

Dry-press bricklets:		
Fire shrinkage	.66	.66
Color	buff brown	red brown
Absorption	16.74	2.03

This clay burns to a good color and should make a good common brick, but it would probably work dry-press, although if molded by the latter method it should be burned to at least cone 03. While its absorption at 2 is very low still it does not make a good vitrified body.

Tramway, Dunn Co. Laminated glacial clays have been worked at this locality to supply a large brick works. The bank here is about 16 feet high consisting of thinly-bedded clay underlain by sand, the former closely resembling the clay at Menomonie. The section of the bank involves:

Sand	4 ft.
Reddish-yellow clay	3 ft.
Bluish clay	3 to 4 ft.
Red clay	4 to 5 ft.
Sand	....

A test of it (Lab. No. 1099) gave the following results: Water required, 33; slaking, fast; plasticity, high; grit, little; air shrinkage, 9.3. Average tensile strength 267.2 pounds per square inch; maximum 296 pounds per square inch. In burning it behaved as follows:

Wet-molded bricklets:				
Cone	010	05	03	1
Fire shrinkage	1	5.7	8.7	vis.
Color	lt. brown	lt. brown	dark bro'n	......
Absorption	17.49	10.17	.05	......
Steel hard at cone	03	....	....	......

Steel hard at cone 03.

Chemical composition.

Silica (SiO_2)	59.26
Alumina (Al_2O_3)	15.12
Ferric oxide (Fe_2O_3)	10.80
Lime (CaO)	3.04
Magnesia (MgO)	.12
Potash (K_2O)	1.97
Soda (Na_2O)	1.63
Titanic acid (TiO_2)	.08
Loss on ignition	8.23
Total	100.25
Total fluxes	17.59

Uses. The clay is extensively used to make an excellent grade of common brick which are molded in a soft-mud machine and burned in scove kilns.

Menomonie, Dunn Co. Laminated glacial clays are worked by three different companies at this town. They are the Wisconsin Red Pressed Brick Co., the Excelsior Brick Co., and the Menomonie Hydraulic Pressed Brick Co. The first two are soft-mud plants, while the latter operates both soft-mud and dry-press machines. The general section of this region involves a surface loam whose thickness is usually from 5 to 3 feet, overlying a laminated clay whose thickness is not less than 50 feet. Their usual character can be obtained from the following section shown in the bank of the Wisconsin Red Pressed-Brick Co.

Gravelly stripping	5 to 7 ft.
Clay	3 to 6 ft.
Sand	4 ft.
Sandy clay	6 ft.
Sand	6 ft.

Or, another section from the bank of the Excelsior Brick Company involved:

Gravelly and sandy stripping	6 to 8 ft.
Laminated clay	25 to 30 ft.
Yellow clay	8 to 12 ft.

These clays are all red-burning, of somewhat silty character and adapted chiefly to the manufacture of soft-mud common brick. The material used for dry-press brick is the sandy loam immediately underlying the surface on the hills near the works of the Menomonie Hydraulic Pressed-Brick Co. While the clays burn rapidly to a hard body and vitrify at a comparatively low temperature still the brittle character of the vitrified clay together with the fact that the points of vitrification and viscosity of the two clays are so close together prevents their being employed for the manufacture of paving brick. Some few vitrified brick are obtained from the arches of the kiln, but it would be impossible to burn a whole kiln full like these. The following tests will give a good idea of the physical characters of the deposits in this area.

Firm	Wisconsin Pressed Brick Co.	Excelsior Brick Co.	Menomonie Hyd. Pressed Brick Co.
Material	Run of bank	Lower blue	Surface loam being soft mud brick
Lab. No	1037	1038	1107
Soluble salts	.56	.46	.23
Water required	26.4	24.2	22
Slaking	moderately fast	moderately fast	....
Plasticity	high	good	moderate
Grit	some, coarse	little	much, fine
Air shrinkage	7.24	6.7	3.9
Average tensile strength	261.9	249	270
Maximum tensile strength	271	314	281
Wet-molded bricklets—			
Cone 010:			
Fire shrinkage	.7	1.6	0
Color	red	red	yellow brown
Absorption	15.70	16.26	12.98
Cone 05:			
Fire shrinkage	2	3	0
Color	red	red	red brown
Absorption	11.66	9.30	15.70

Cone 03:			
Fire shrinkage	7.8	8	1
Color	dark red	red	brown
Absorption	3.40	1.90	12.50
Cone 1:			
Fire shrinkage	vis.	1.7	....
Color	....	dark red	brown
Absorption	....	.70	2.83
Steel hard at cone	....	05	1
Dry-press bricklets— Cone 05:			
Fire shrinkage	.66	....	....
Color	light brown	....	red
Absorption	16.69	....	....

1037. The large brick cracked some when subjected to rapid drying. The clay gives a good hard body even at 010 but the color deepens too much if burned to cone 03 or above.

1038. This brick cracks badly if dried rapidly but the clay makes a good red brick whose color is less pronounced if burned above 05. It is not adapted for the manufacture of vitrified brick.

1107. This clay gives a good common soft-mud brick or even dry-press body but if burned about cone 03 the color becomes rather deep.

The chemical analysis of two of the above clays was as follows:

Laboratory No	1037	1038
Silica (SiO_2)	65.46	60.20
Alumina (Al_2O_3)	11.38	14.48
Ferric oxide (Fe_2O_3)	6 40	8.70
Lime (CaO)	2.06	2.84
Magnesia (MgO)	1.63	2.40
Potash (K_2O)	3.54	4.50
Soda (Na_2O)	.98	.53
Titanic acid (TiO_2)	.07	.03
Loss on ignition	8.25	6.73
Total	99.77	100.46
Total fluxes	14.61	18.97

St. Croix Falls, Polk Co. A sandy surface clay has been opened up at the brick yard of August Dombruck three miles east of St. Croix Falls. It is a laminated red glacial clay 8 feet thick and the more plastic swamp clay has to be mixed with it to make a good brick. The clay burns to a good cherry-red color and is molded by the soft-mud process.

Chippewa Falls, Chippewa Co. While the surface material throughout this region is mostly sand, still here and there, especially in the hollows, there are surface deposits of siliceous clay which are adapted to the manufacture of common brick, but are not sufficiently fine grained to make drain tile or common red earthenware. These are at present being worked at two yards namely those of the Chippewa Falls Brick Co. and Thierault's yard. The properties of these two were as follows:

Firm	Chippewa Brick Mfg. Co.	Thierault's
Material	Brick clay	Brick mixture
Laboratory No.	1029	1179
Water required	26.4	23.1
Plasticity	good	fair
Grit	....	much, fine
Air shrinkage	5.4	4.7
Wet-molded bricklets—		
Cone 010:		
Fire shrinkage	.6	sl. sw.
Color	light red	yellow brown
Absorption	15.76	17.40
Cone 05:		
Fire shrinkage	.5	sl. sw.
Color	medium red	yellow brown
Absorption	13.84	16.66
Cone 03:		
Fire shrinkage	1.7	1
Color	medium red	light red brown
Absorption	11.27	14.14
Cone 1:		
Fire shrinkage	6.7	2.4
Color	dark red	red brown
Absorption	1.95	10.46
Cone 2:		
Fire shrinkage	6.7	
Color	dark brown	
Absorption	1.17	
Steel hard at cone	1	

Steel hard at cone 1.

1029. This clay gives a fairly good body even at cone 010 and burned very hard at cone 1, but its fire shrinkage at this point is rather high. The color of the clay is also bright up to 05 but deepens considerably above this.

No. 1179 is similar to 1029, but has a lower fire shrinkage.

At both yards the clay is used for making soft-mud brick and is burned in scove kilns.

Whittlesey, Taylor Co. The Langenberg Brick Co. has a yard at this locality which is 5 miles north of Medford. The material (Lab. No. 1048) is a silty surface clay found on both sides of a small stream, and is probably not more than 8 feet in thickness, but only the upper 5 feet are used.

Its physical properties are as follows: Water required, 27.5; plasticity, good; grit, some, coarse; air shrinkage, 6.9. In burning it behaved as follows:

Wet-molded bricklets:				
Cone	010	05	03	1
Fire shrinkage	.3	2.3	5.7	5.7
Color	light red	dark red	dark red	dark red
Absorption	14.22	8.68	5.70	.80
Steel hard at cone 03.				

Steel hard at cone 03.

This is an excellent common-brick clay and gives a good red brick even at cone 010, but the color deepens considerably at 03. At cone 1 the body is nearly vitrified but the material is too silty to make a paving brick.

Uses. It is employed at the present time for making common brick which are molded in a soft-mud machine or a Swords machine the former giving much better results. The brick are dried on pallets and burned in scove kilns.

Merrill, Lincoln Co. There are two small yards in operation about two miles south of town one of these being run by P. Myers and the other by A. Boetcher. The clays are both silty surface clays which are dug to a depth of about two feet. That at Myers' yard (Lab. No. 1135) slakes moderately fast and works up with 20.9 per cent water to a mass of fair plasticity containing much silt, and whose air shrinkage is 3.7 In burning it behaved as follows:

Cone	010	05	03
Fire shrinkage	sl. sw.	0	1.6
Color	brownish yellow	yellow brown	red brown
Absorption	15.04	14.98	11.29

The clay burns to a good red color even at cone 010 but it does not yield a very dense brick.

Schulz's Spur. This point is located along the St. Paul Railroad north of Merrill and the clay bank is east of the track. The deposit is known to run about 17 feet deep and is underlain by sand. For molding the run of the bank is used. The clay (Lab. No. 1146) which is rather silty and of low plasticity works up with 17.6 per cent of water to a mass whose air shrinkage is 7.1. The average tensile strength is 272 pounds per square inch with a maximum of 305 pounds per square inch. In burning it behaved as follows:

Wet-molded bricklets:				
Cone	010	05	03	1
Fire shrinkage	sl. sw.	0	.6	6
Color	brownish yellow	red brown	light buff	brown
Absorption	14	12.33	10.30	2.19

It burns steel hard at cone 1.

Uses. This is an excellent common-brick clay but should be burned to at least 010 in order to give a strong product. It is employed for making common brick.

Superior, Douglas Co. Surrounding this town is an extensive deposit of red clay containing many scattered lime pebbles. Attempts have been made to work it, but these have been mostly without success, it being claimed that the lime pebbles in the material rendered it impossible to produce a good grade of brick. The clay is very dense and plastic and occurs at no great depth below the surface, being thrown out from almost every cellar or other excavation. One sample of this (Lab. No. 1180) was tested from the city of Superior with the following results: It worked up with 32.5 per cent of water which is much higher than that required by most other clays in the state and developed a highly plastic mass with some coarse grit. Its air shrinkage was 10.5 per cent. The average tensile strength was about 200 pounds per square inch but it was very difficult to get briquettes free from flaws on account of the tendency of the material to crack in air drying. The wet-molded bricklets in burning behaved as follows:

Cone	010	05	03	1
Fire shrinkage	.3	3	8.6	vis.
Color	pinkish	pinkish	red brown	....
Absorption	19.53	12.18	.80	....

The clay shows a tendency to crack badly in air drying an even in burning and on this account it was worked with difficult if used alone and molded either by the stiff or soft-mud proces It burns steel hard at cone 05 and is of low fusibility. If it i used for brick making it should be worked preferably on a stiff-mud machine, and even then it should be burned to a temperature of not less than cone 05.

Judging from the bricks that are to be seen in some of the old buildings in Superior the clay when formerly used was probably not burned at as high a temperature even as cone 010.

The chemical analysis of the material gave:

Silica (SiO_2)	54.36
Alumina (Al_2O_3)	13.40
Ferric oxide (Fe_2O_3)	7.97
Lime (CaO)	3.50
Magnesia (MgO)	1.23
Potash (K_2O)	2.16
Soda (Na_2O)	1.53
Titanic acid (TiO_2)	.07
Loss on ignition	16.17
Total	100.39
Total fluxes	16.30

Discussion of physical tests of red-burning surface clays. The clays of this group are usually surface deposits, ranging from average to high grittiness. Owing to their gritty character they usually slake fast. Their plasticity is variable, but the majority are from good to highly plastic. The water required for mixing ranged from 13.2 per cent to 34.1 per cent in 51 samples, with an average of 23.2 per cent, but in the majority it was under 25 per cent.

There was a corresponding variation in air shrinkage from 3.1 per cent to 10.5 per cent, with an average of 6.04 per cent. The variation in air shrinkage was greater in this class than any others.

The tensile strength of 20 representative samples was tested, and ranged from 75.3 pounds per square inch to 327 pounds

per square inch with an average of 249.2 pounds per square inch. This seems to be a large variation and it should be stated that 18 of the 20 tested had a strength of 200 pounds or over.

Nearly all the clays of this group burned to a red or red-brown color, of varying degrees of intensity. At cone 010 most of them showed little or no fire shrinkage and some even swelled slightly. Only one was steel hard. The absorption ranged from 11.23 to 54.34 per cent, the majority however falling below 18 per cent.

At cone 05 there was a slight increase in the shrinkages, those from Menomonie and Tramway showing the highest. The colors in most cases were slightly deeper than at cone 010. The absorption range was less running from 3 to 29.78 per cent. The decrease in absorption from cone 010 to cone 05 was slight in most of the samples tested, the greatest change being noted in the fine grained more easily fusible ones. At cone 03 the absorption ranged from .05 to 28.40 per cent, but one-half of the clays absorbed less than 1 per cent. The fire shrinkage of most of the samples was still small.

At cone 1 the absorption in most cases was quite low, and the fire shrinkage low or moderate. A number of the clays had become steel hard, but a few such as those from Menomonie were nearly viscous. The majority, however, did not become viscous until at least cone 3.

Most of the clays of this group burn to a good brick at cone 010. As compared with the residual clays, they are usually more refractory, but do not give a much denser body at the lower cones. Comparing them with the cream-burning calcareous clays, we find that they do not show as much tendency to swell above cone 010, are denser burning, harder in firing at a lower cone, and show about the same range of viscosity.

The chemical analyses show that the clays of this subgroup are with few exceptions rather siliceous, and sometimes rather high in alkalies. That from Iron Ridge is low in silica and high in lime and magnesia but still there is also a high iron percentage and consequently the clay burns more of a brown than a buff.

Red-burning clays.

Lab. No	Locality.	Silica (SiO_2)	Alumina (Al_2O_3)	Ferric oxide (Fe_2O_3)	Lime (CaO)	Magnesia (MgO)	Potash (K_2O)	Soda (Na_2O)	Titanic acid (TiO_2)	Loss on ignition	Total	Total fluxes	Analyst
1012	Milton	71.56	11.15	3.73	1.70	.96	2 41	1.28	.. ..	6.33	99.12	10.08	V. Lenher.
1073	Kenosha ... (upper.)	55.41	18.10	5.91	6.28	.14	1.54	.49	.25	12.34	100.46	14.36	V. Lenher.
1027	Iron Ridge.	30.90	7.96	9.13	17.30	4.80	3.75	.37	.09	25.30	99.60	35.35	V. Lenher.
	(upper.) Viroqua....	74.71	12.60	2.80	.70	.55	2.18	1.14	.55	5.30	100.53	7.37	S. Peppel.
	Viroqua....	78.26	11.41	1.80	1.00	.68	1.88	1.28	.45	3.12	99.88	6.64	S. Peppel.
1077	Arcadia....	73.08	11.56	4.11	.84	.52	2.31	2.75	.09	5.36	100.62	10.53	V. Lenher.
1169	Marshfield..	72.60	12.16	5 66	1.34	.08	2.47	1.44	....	4.07	99.86	10.99	V. Lenher.
1085	Hewitt.....	75.24	12.21	3.89	1.74	1.01	2.56*		....	3.35	100.00	9.20	A. S. Mitchell
1050	Edgar......	64.46	8.73	5.40	7.32	.16	1.45	1.44	.01	11.10	100.07	15.77	V. Lenher.
1099	Tramway ..	59.26	15.12	10.80	3.04	.12	1.97	1.63	.08	8.23	100.25	17.59	V. Lenher.
1037	Menomonie	65.46	11.38	6.40	2.06	1.63	3.54	.98	.07	8.25	99.77	14.61	V. Lenher.
1038	Monomonie	60.20	14.48	8.70	2.84	2.40	4.50	.53	.03	6.73	100.46	18.97	V. Lenher.
1180	Superior ...	54.36	13.40	7.97	3.50	1.23	2.16	1.53	.07	16.17	100.39	16.39	V. Lenher.

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* By difference.

III. WHITE-BURNING CLAYS OF REFRACTORY CHARACTER. Deposits of a white-burning clay have in the past been worked in the region north of Hersey. The clay found there is stratified, and contains more or less sand which has to be removed from it by washing. The washed product has been sold chiefly for use in paper manufacture. The washing plants which were at one time built near Hersey and also Glenwood have been dismantled and the pits have washed in so that no information was obtainable concerning the character of the clay. The beds, however, have been described in some detail in Dr. Buckley's bulletin.[*]

In the event of new deposits being discovered in this region, it will be of interest and value to know that the tests which have been made on the washed clay from this locality show that it can be used for white earthenware manufacture with simply the addition of flint and feldspar, ball clay being unnecessary. The Hersey washed clay is also quite refractory its fusing point being the same as that of cone 32.

The crude clay contains much fine silt which it is difficult to eliminate even by washing.

Kaolins in the central residual area. Rumors have been circulated from time to time regarding the existence of kaolin deposits in the residual clay belt, and during the course of the field work every reasonable effort was made to find such deposits if they existed. Only two were heard of. One of these was a pit near South Centralia which was worked a number of years ago for fire clay to supply foundries, and is now exhausted.

The other lies about 6 miles east of Eau Claire where in an artificial cut a vein of whitish clay about 6 feet wide was seen. Samples taken from this showed that it is not white-burning even at low temperatures, but fires to a grayish brown body. The deposit, aside from this, is of too small size to be of any economic value.

IV. SLIP CLAYS.

IV. SLIP CLAYS. Under this heading are included easily fusible clays, which are used for glazing, and applied by mixing the clay with sufficient water to give the mixture a creamy consistency and either dipping the ware in this, or spraying the slip on its surface. A slip clay* should be fine grained, with a low shrinkage and must mature as little above 2250° F. as possible. The proportion of lime and magnesia must be high, ranging from 6–12 per cent. The iron oxide content should be sufficient to produce a brown color, viz. 5–7 per cent. A high alkali content is also essential to promote fusion. The following are analyses of several slip clays mined in the United States.

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[*] Bull. VII, Wis. Geol. & Nat. Hist. Surv., p. 234.

	Albany, N. Y.	Rowley, Mich.	Brim-field, O.
Silica (SiO_2)	55.60	43.94	63.63
Alumina (Al_2O_3)	14.80	11.17	13.57
Ferric oxide (Fe_2O_3)	5.80	3.81	7.77
Lime (CaO)	5.70	11.64	2.55
Magnesia (MgO)	2.48	4.70	1.47
Potash (K_2O)	3.23	3.61	2.63
Soda (Na_2O)	1.03	....	....
Manganese (MnO)	.14	....	....
Water (H_2O)	5.18	3.90	4.75
Moist and carbonic acid	4.94	15.66	2.90
Phosphoric acid (P_2O_5)	.15	....	....
	99.14	98.43	99.27

The molecular formula of each of these is as follows:

$$1.\quad \left.\begin{array}{l} .158\ K_2O \\ .079\ Na_2O \\ .469\ CaO \\ .286\ MgO \\ .009\ MnO \end{array}\right\} \left.\begin{array}{l} .668\ Al_2O_3 \\ .161\ Fe_2O_3 \end{array}\right\} 4.27\ SiO_2$$

$$2.\quad \left.\begin{array}{l} .066 \left\{\begin{array}{l} K_2O \\ Na_2O \end{array}\right. \\ .596\ CaO \\ .337\ MgO \end{array}\right\} \left.\begin{array}{l} .314\ Al_2O_3 \\ .066\ Fe_2O_3 \end{array}\right\} 2.109\ SiO_2$$

$$3.\quad \left.\begin{array}{l} .169 \left\{\begin{array}{l} K_2O \\ Na_2O \end{array}\right. \\ .459\ CaO \\ .370\ MgO \end{array}\right\} \left.\begin{array}{r} 1.343\ Al_2O_3 \\ .489\ Fe_2O_3 \end{array}\right\} 10.71\ SiO_2$$

Wisconsin slip clays. Among the Wisconsin clays tested there were found several of sufficiently low fusibility to use as a slip, which are mentioned below.

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*Williams, Iowa Geol. Survey, Vol. XIV, p. 225, 1904.

1. Burlington. (Lab. No. 1051.) This represents the lower blue clay from the Burlington Brick and Tile Works. It is a fine-grained calcareous clay whose composition is.

Silica (SiO_2)	41.66
Alumina (Al_2O_3)	14.31
Ferric oxide (Fe_2O_3)	6.69
Lime (CaO)	9.38
Magnesia (MgO)	4.75
Potash (K_2O)	3.73
Soda (Na_2O)	.92
Titanic oxide (TiO_2)	.05
Ignition	17.86
	99.55

This corresponds to a formula of

$$\left.\begin{array}{l} .116\ K_2O \\ .043\ Na_2O \\ .491\ CaO \\ .348\ MgO \\ \hline .998 \end{array}\right\} \begin{array}{l} .411\ Al_2O_3 \\ .122\ Fe_2O_3 \end{array} \left\{\begin{array}{l} 2.048\ SiO_2 \\ .001\ TiO_2 \end{array}\right.$$

At cone 5 it gives a brownish-yellow slip.

2. Kenosha. The upper clay at W. J. Craney's yard was also tried. This has a composition of

Silica (SiO_2)	38.62
Alumina (Al_2O_3)	8.75
Ferric oxide (Fe_2O_3)	8.22
Lime (CaO)	14.04
Magnesia (MgO)	6.27
Potash (K_2O)	2.65
Soda (Na_2O)	.89
Titanic acid (TiO_2)	.07
Ignition	19.99
Total	99.50

Its formula would be

$$\left.\begin{array}{l} .063\ K_2O \\ .031\ Na_2O \\ .556\ CaO \\ .347\ MgO \end{array}\right\} \begin{array}{l} .190\ Al_2O_3 \\ .113\ Fe_2O_3 \end{array} \left\{\begin{array}{l} 1.428\ SiO_2 \\ .001\ TiO_2 \end{array}\right.$$

This gives an olive-colored glaze but not a very smooth one, as the clay appears to be too silty.

3. Green Bay. A sample of clay from Eiserman's yard burned at cone 6 gave a deep brown glaze when applied thick and a yellowish-brown one in thin coats.

4. At Sheboygan, there is a thin bed of red clay, overlying the cream-burning clay at the O. Zimbal Brick Co.'s yard, whose chemical composition is

Silica (SiO_2)	59.22
Alumnia (Al_2O_3)	16.65
Ferric oxide (Fe_2O_3)	7.72
Lime (CaO)	.96
Magnesia (MgO)	.52
Potash (K_2O)	2.78
Soda (Na_2O)	1.94
Titanic acid (TiO_2)	.03
Ignition	10.23
Total	100.05

The formula for this is

$$\left.\begin{array}{l}.324\ \mathrm{K_2O}\\ .343\ \mathrm{Na_2O}\\ .188\ \mathrm{CaO}\\ .143\ \mathrm{MgO}\end{array}\right\}\begin{array}{l}1.795\ \mathrm{Al_2O_3}\\ .530\ \mathrm{Fe_2O_3}\end{array}\left\}\begin{array}{l}10.87\ \mathrm{SiO_2}\\ .003\ \mathrm{TiO_2}\end{array}\right.$$

5. Medford. The residual clay derived from the diorite at this locality (See p. 131) analyzed.

Silica (SiO_2)	45.65
Alumina (Al_2O_3)	18.90
Ferric oxide (Fe_2O_3)	18.00
Lime (CaO)	.86
Magnesia (MgO)	.29
Potash (K_2O)	7.66
Soda (Na_2O)	1.70
Titanic acid (TiO_2)	.03
Ignition	6.55
Total	99.64

This analysis would give the following formula:

$$\left.\begin{array}{l}.619\ \mathrm{K_2O}\\ .208\ \mathrm{Na_2O}\\ .116\ \mathrm{CaO}\\ .054\ \mathrm{MgO}\end{array}\right\}\begin{array}{l}1.410\ \mathrm{Al_2O_3}\\ .856\ \mathrm{Fe_2O_3}\end{array}\left\}\begin{array}{l}5.794\ \mathrm{SiO_2}\\ .002\ \mathrm{TiO_2}\end{array}\right.$$

At cone 1 it gives a deep red, dull matte-like glaze, but does not yield a good glaze at higher cones.

6. Platteville. Underlying the oil rock at the Capitola Mine locality there is a three-foot layer of soft grayish-gray shale of low fusibility. Its composition as determined by R. C. Benner on two separate samples was as follows:

Silica (SiO_2)	59.80	60.36
Alumina (Al_2O_3)	18.13	18.21
Ferric oxide (Fe_2O_3)	2.57	4.11
Lime (CaO)	1.80	.36
Magnesia (MgO)	.66	.13
Potash (K_2O)	10 27	9.84
Soda (Na_2O)	.71	1.38
Titanic acid (TiO_2)	.12	.06
Ignition	6.56	5.97
Total	100.62	100.42
Total fluxes	16.01	15.82

The molecular formulæ are:

$$\left.\begin{array}{l} .645\ K_2O \\ .067\ Na_2O \\ .189\ CaO \\ .097\ MgO \end{array}\right\} \begin{array}{r} 1.05\ Al_2O_3 \\ .949\ Fe_2O_3 \end{array}\left\}\begin{array}{r} 5.89\ SiO_2 \\ .008\ TiO_2 \end{array}\right.$$

$$\left.\begin{array}{l} .766\ K_2O \\ .162\ Na_2O \\ .046\ CaO \\ .023\ MgO \end{array}\right\} \begin{array}{r} 1.308\ Al_2O_3 \\ .187\ Fe_2O_3 \end{array}\left\}\begin{array}{r} 7.375\ SiO_2 \\ .005\ TiO_2 \end{array}\right.$$

CHAPTER V.

TESTS OF WISCONSIN BRICKS.

In order to test the qualities of the bricks made in Wisconsin, a number of samples were collected from different localities, ninety-one in all. Ten bricks were collected from each locality, normally burned ones being selected as far as possible, either from the kiln or the stock pile. In a few instances underburned or hard-burned bricks were taken in addition to the normally burned ones.

The samples thus selected were shipped to the University of Wisconsin at Madison, and tested in the Engineering Laboratory by Messrs. C. V. Hopper and L. F. Van Hagen.

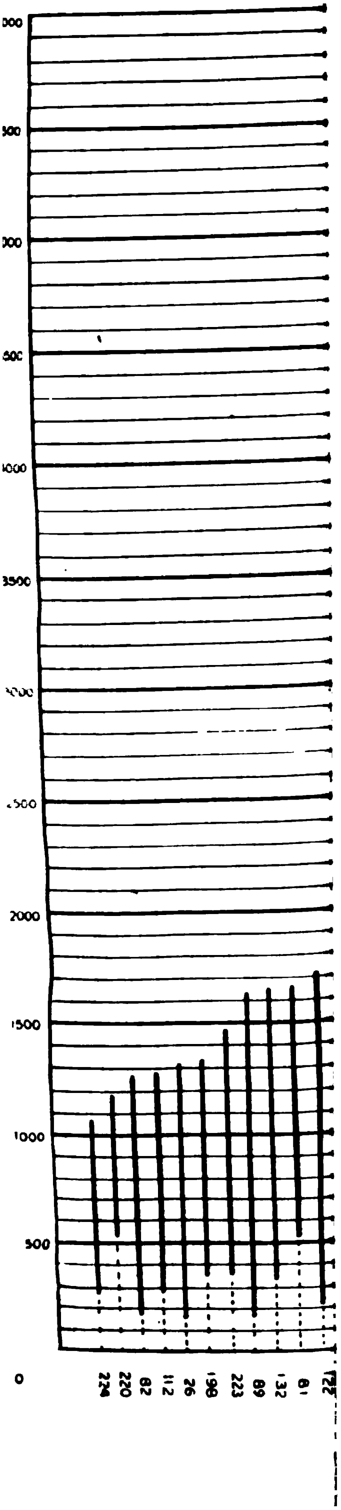
Each set of bricks was tested for (1) its crushing strength; (2) its transverse strength, and (3) its absorption. In every case 5 bricks were crushed in order to give a reliable average, and the results are given in detail in the table on p. 193. Each manufacturer has been furnished with a copy of the test made on his own brick, although in this report no names are published in connection with these tests.

EXPLANATION OF TESTS.

CRUSHING TEST. This test was made for the purpose of determining the number of pounds pressure per square inch that the brick will stand without crushing. The strength will naturally vary with the density of the brick, degree of hardness to which it has been burned, character of the raw material, and amount of care taken in the manufacture.

Few bricks show a chushing strength of less than 2,000 lbs. per square inch, while some even exceed 15,000 lbs. per square inch, but none of the Wisconsin bricks reached the higher limit and few fell below the lower one. As a matter of fact, however, bricks when set in a wall are seldom compelled to stand the weight they are capable of resisting.

WISCONSIN GEOL. AND NAT. HIST. SURVE



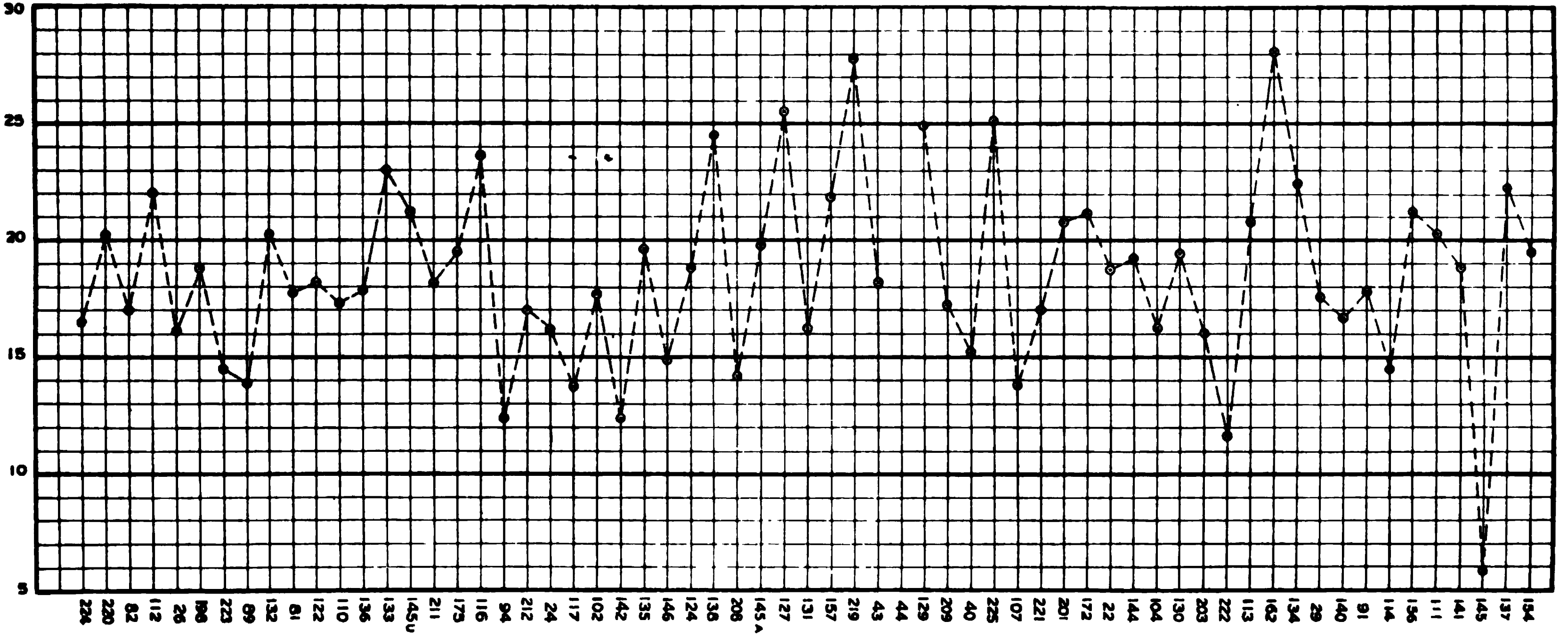


Fig. 2. Absorption tests on Wisconsin soft mud brick, made after 48 hours immersion.

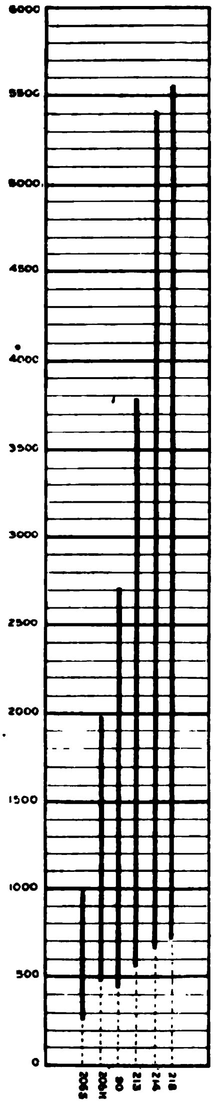


Fig. 1. Crushing and transverse tests on Wisconsin dry press brick.

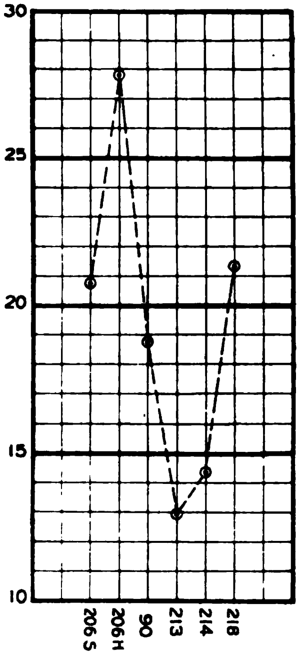


Fig. 2. Absorption tests of Wisconsin dry press brick, made after 48 hours immersion.

The test to determine a brick's crushing strength is commonly made in a specially constructed machine. Half bricks are usually tested, because a whole brick has so large a surface area that it sometimes resists a greater load than the machine is capable of supplying. Before crushing, the two opposite surfaces of the brick (in this case the top and bottom) must either be ground perfectly smooth and parallel, or else they must be built up to this condition by the application of a layer of plaster of paris. The reason for this is that in the testing machine the brick is set between two steel surfaces, and unless its surface fits perfectly against these, the pressure will not be evenly distributed.

Before crushing, the area of the brick's surface is measured, and, the total load necessary to crush the brick, divided by this area, gives the crushing strength in pounds per square inch.

TRANSVERSE STRENGTH. This is more important even than the crushing strength, for while a brick is rarely loaded to its crushing limit, it is sometimes exposed to its limit of elasticity and cracked.

In the cross-breaking test a whole brick was placed on two rounded knife-edge bearings 6 inches apart. Pressure was then applied from above, until the brick broke in two and the number of pounds pressure at which this occurred noted. It is evident that in two bricks of exactly the same degree of strength the amount of pressure necessary to break them will depend upon the distance between the supports and the cross section of the brick. The farther apart the supports the less pressure necessary. Since this is so, it is necessary that for purposes of comparison all results of the breaking strength shall be reduced to some uniform expression which shall take account of the differences of length, width and thickness of the brick. The most accurate expression is that termed the *modulus of rupture,* which is calculated from the following formula.

$$R=\frac{3\,Wl}{2\,bh^2}$$

in which R=Modulus of Rupture

W=Pressure necessary to break the brick

l =Distance between the supporting knife edges

b =Breadth of the brick

h =Thickness of the brick

This means, that three times the pressure in pounds multiplied by the distance between the supports, is divided by twice the breadth of the brick multiplied by the square of the thickness. If the pressure necessary to break a brick was 1,500 pounds, distance between supports 6 inches, width of brick 4 inches and thickness 2 inches, the modulus of rupture would be calculated as follows:

$$\frac{3 \times 1500 \times 6}{2 \times 4 \times 2_2} = 843.7 \text{ pounds}$$

Absorption Test. An absorption test is made for determining how much water a brick is capable of absorbing. This indicates approximately the degree of porosity which it possesses. Vitrified brick are impervious or nearly so, and absorb little or no water, while many common brick may absorb 15 or 20 per cent and some of the Wisconsin ones absorbed over 30 per cent. It is easily understood that if a brick of high porosity is exposed to a freezing temperature when its pores are filled with water, the expansion of the latter, when changing to ice, *may* be sufficient to disrupt the brick, either after one freezing, or after repeated freezings following periods of thawing. A moderate or low absorption is therefore desirable.

The absorption test was made on half brick which were carefully dried, weighed, soaked for 48 hours in water, and weighed again, the increase in weight showing the amount of water absorbed. The percentage of absorption was calculated in terms of the original or dry weight.

Objections have been urged by some to this method of determining the absorptive power of a brick, it being claimed that the pores of the brick do not become completely filled with water, and that a better way is to place the brick in a vacuum while it is immersed. In making absorption tests we should not forget that we are trying to duplicate as nearly as possible the conditions to which the brick will be exposed when in actual use. Under such conditions a brick is not exposed to a vacuum, but absorbs moisture while exposed to ordinary atmospheric pressure, and consequently by the vacuum method we are forcing the brick to absorb much more water than it would when in use, and are obtaining results of comparatively little practical value.

The writer does not feel either that the total immersion of the brick is the best way of testing its absorption, but that partial immersion will yield the most satisfactory results. With this last mentioned method the brick is immersed to perhaps two thirds its depth in water, which allows the liquid to be drawn into the pores by capillarity while the air in the interspaces of the brick can readily escape.

In testing the Wisconsin bricks the absorption by all three methods was tried, and the results of this are given below:

Stiff Mud Bricks

Lab. number.	Per cent. absorption. Complete immersion 48 hrs.	Per cent. absorption. Partial immersion 4 hrs.	Per cent. absorption. Partial immersion 48 hrs.	Percentage of total absorption which 4 hrs. partial immersion represents.	Per cent. absorption 48 hrs. total immersion under vacuum.	Per cent. gain of 48 hrs. total immersion under vacuum over same in normal atmospheric pressure.
I.	II.	III.	IV.	V.	VI.	VII.
28	24.15	24.0	24.95	96.15	30.4	25.8
28 A	14.5	14.45	15.15	95.35	18.8	29.6
35	14.4	12.1	12.7	95.2	18.35	27.4
45	23.2	20.35	21.45	94.85	25.35	9.2
80	20.55	17.35	18.3	94.8	26.65	29.6
83	21.75	19.5	20.45	95.3	24.85	14.2
98	13.05	12.05	14.3	84.25	18.5	41.7
99	34.3	30.65	32.0	95.75	39.9	16.3
128	27.6	24.65	25.55	96.25	28.65	3.5
143	20.55	19.15	20.75	92.25	22.6	9.9
147	23.2	22.55	23.6	95.5	27.65	19.1
158	20.85	19.45	20.3	94.9	27.75	33.0
163	18.05	16.9	18.0	93.8	21.1	16.8
164	16.7	20.7	21.0	98.5	24.6	47.3
202	16.6	18.35	18.85	97.3	24.6	48.1
205	19.55	20.95	22.25	94.1	25.4	29.9
207	24.15	20.1	24.85	80.8	30.	24.2
210	21.1	19.85	21.7	91.4	26.0	23.4
215	25.35	25.15	25.95	96.85	30.4	19.9
216	19.6	20.3	20.95	96.85	26.75	36.4
217	19.95	16.8	17.9	92.7	33.85	69.6

Soft Mud Bricks.

Lab. number.	Per cent. absorption. Complete immersion 48 hrs.	Per cent. absorption. Partial immersion 4 hrs.	Per cent. absorption. Partial immersion 48 hrs.	Percentage of total absorption which 4 hrs. partial immersion represents.	Per cent. absorption 48 hrs. total immersion under vacuum.	Per cent. gain of 48 hrs. total immersion under vacuum over same in normal atmospheric pressure.
I.	II.	III.	IV.	V.	VI.	VII.
19 B	18.85	18.85	19.0	99.15	19.5	3.4
22	18.7	19.25	19.9	96.7	27.15	45.1
24	16.2	16.45	17.1	96.1	21.85	34.8
26	16.3	15.25	16.05	95.00	20.20	23.9
29	17.15	15.45	16.2	95.3	21.25	23.9
40	15.2	12.75	13.5	94.4	18.25	19.7
43	18.05	17.25	18.2	94.75	26.1	44.5
44	....	18.6	19.25	96.55	25.05	....
81	17.5	12.1	13.05	92.14	18.65	6.5
82	17.15	14.7	15.55	94.5	20.4	18.9
89	13.9	12.75	13.45	94.8	17.1	23.0
91	17.75	17.6	18.2	96.65	20.5	10.9
94	12.25	12.75	13.55	93.3	19.45	58.7
102	17.75	17.15	18.00	95.2	23.3	31.2
104	16.4	15.3	15.8	96.85	20.45	24.7
107	13.8	12.9	13.4	96.25	19.2	39.1
110	17.2	16.75	17.5	95.65	23.65	37.5
111	20.25	15.05	15.35	98.05	21.7	7.1
112	22.25	18.05	19.4	93.0	25.35	13.9
113	20.6	17.4	18.9	92.05	26.00	26.2
114	14.4	12.65	13.	97.3	17.3	20.1
116	23.65	24.05	25.15	95.55	27.7	17.1
117	13.6	13.05	13.5	96.6	14.95	9.9
122	18.15	17.0	17.95	99.65	22.9	26.1
124	18.55	17.5	13.05	96.9	22.8	22.9
127	25.55	23.75	25.05	94.8	31.65	24.6
129	25.0	23.65	25.7	92.00	30.00	20.00
130	19.45	22.8	23.5	97.00	26.25	34.9
131	16.1	15.65	16.2	96.55	19.15	18.1
132	20.35	19.5	20.45	95.3	24.9	22.3
133	23.2	21.0	21.95	95.6	24.9	7.3
134	22.4	20.9	21.7	96.35	24.55	9.5
135	19.6	14.5	15.25	95.1	19.65	2.5
136	17.95	16.95	18.00	94.1	23.2	29.2
137	22.25	21.6	22.4	96.6	26.2	17.7
138	24.65	21.4	22.55	90.8	26.9	9.1
140	16.75	16.7	17.55	95.1	21.1	25.9
141	18.9	16.35	18.35	91.65	26.9	42.8
142	12.3	9.85	11.00	90.4	16.1	30.8

Soft Mud Bricks—Continued.

Lab. number.	Per cent. absorption. Complete immersion 48 hrs.	Per cent. absorption. Partial immersion 4 hrs.	Per cent. absorption. Partial immersion 48 hrs.	Percentage of total absorption which 4 hrs. partial immersion represents.	Per cent. absorption 48 hrs. total immersion under vacuum.	Per cent. gain of 48 hrs. total immersion under vacuum over same in normal atmospheric pressure.
I.	II.	III.	IV.	V.	VI.	VII.
144	19.25	16 3	16.75	97.25	19.7	2.3
*145A	19.5	25.0	26.15	95.55	30.45	61.2
†145U	21.3	16.2	16.35	99.0	18.45	lost
146	14.95	14.0	14.75	94.85	17.5	17.0
154	19 45	21.55	23.2	92.85	26.15	34.4
156	21.15	19.65	21.00	93.6	27.75	31.2
157	21.75	23.00	24.1	95.35	30.25	39.0
162	28.2	24.2	25.25	95.8	30.6	8.5
172	21.15	20.25	22.75	89.0	31.5	48.9
175	19.6	16.75	17.55	95.4	21.85	11.4
201	20.85	16.45	17.35	94.8	24.0	15.1
203	16.3	12.3	13.2	93.1	23.05	41.4
208	14 1	13.6	14.35	94.7	19.15	35.8
209	17.2	16.6	16 95	97.9	21.9	27.3
211	18.15	18.8	19.35	97.1	23.0	26.7
212	17.0	19.35	20.4	96.3	26.85	57.9
219	27.95	27.6	28 7	96.1	33.4	19.4
220	20.35	17.55	18.3	95.85	21.05	3 4
221	16.9	17.8	18.0	98.8	21.45	26.9
222	11.55	11.75	12.0	97.9	16.1	39.3
223	14.55	15.55	16.25	95.6	21.0	44.3
224	16.45	15.8	16.95	93.2	21.5	30.7
225	25.1	24.65	26.2	92 0	32.35	28.8

Dry Press Brick.

90	18 75	12 25	18 7	92.2	24.15	28.8
206H	33.35	27.5	28.75	95.8	34.6	3.70
206S	27.95	31.7	33.2	95.4	38.3	37.0
213	12.9	12.95	13.1	98.8	15.7	21.7
214	14.35	14.6	14.75	98 95	17.05	18.8
218	21.5	22.6	23.0	97.95	27.2	26 5

In this table column II represents the average percentage of absorption obtained by immersing two half brick in water for 48 hours.

Two other half brick from the same lot were immersed to half their depth in water. At the end of 4 hours these were taken out and the gain in weight noted, the percentage of absorption determined from this being given in the column III. These two samples were put back into the water and allowed to remain 44 hours longer, their absorption being again determined, and the results given in column IV. It was found that in nearly every case, the bricks, at the end of 4 hours had absorbed over 90 per cent, of the total quantity they were capable of absorbing after 48 hours of partial immersion, and these percentages are given in column V. The method of manufacture and degree of density of the brick, did not appear to affect the result in any way whatever. The percentages given in columns II and IV agree quite closely in most cases, although in a few instances they are slightly different, which might be due in part at least to lack of uniformity in the product.

A third pair of half brick were completely immersed in water under a vacuum, so that all the air could be extracted from the pores and the brick become completely saturated. By this means a greatly increased absorption was obtained, the average percentage of which is given in column VI. The per cent gain over the absorption obtained in column II is given in column VII, and it will be seen that it ranges from 2.3 to 69.6 per cent.

In the accompanying table the details of the crushing, transverse, and absorption tests are given, and for greater clearness they are given in condensed form in the diagrams, Plates XVI, XVIa, XVII, and XVIII.

In these diagrams the results are expressed in somewhat different form from that usually adopted, and I take pleasure in here acknowledging that this has been done in accordance with a suggestion from Dr. E. A. Birge. In these diagrams the laboratory number of the brick is given at the bottom and the number of pounds at the side. For each brick a black vertical line is drawn, whose upper end is opposite the number of pounds representing its crushing strength, while the lower end is opposite the number of pounds representing its modulus of rupture. This method of plotting the results brings out more clearly the results obtained, and at the same time shows that the individual sets tested are not related to each other, as might be supposed if all the crushing points and rupture points were connected by a line.

The absorption percentages are given on a separate diagram accompanying the crushing and transverse tests.

DISCUSSION OF TESTS ON BRICK.

Crushing strength. The crushing strength of the Wisconsin brick tested ranged from 993 lbs. per square inch up to 7060 lbs. per square inch.

The range of strength in the several classes is as follows:

Kind.	Minimum.	Maximum.	Average.
Soft mud........................	1,074	5,838	2,829
Stiff mud	1,304	7,060	4,244
Dry press	993	5,558	3,408

This indicates that the average crushing strength of all the stiff-mud and the dry-press bricks made in Wisconsin is higher than the average of the soft-mud bricks. Anyone not acquainted with the character of the clays used might perhaps ascribe this to the process rather than the material.

The true explanation seems to the writer to be this. Most of the stiff-mud brick manufactured in Wisconsin are made from cream-burning clays. These in most cases have to be fired much harder to get a good brick than do the red-burning ones. Consequently the manufacturers of cream brick fire their product as hard as possible, while the red-brick manufacturers knowing that their clays fire easily, do not take the trouble to fire them hard.

Transverse strength. The transverse strength of all kinds of Wisconsin clay bricks tested ranged from 157 lbs. to 1027 lbs. Classified by kinds the range was as follows.

Kind.	Minimum.	Maximum.	Average.
Soft mud	157	1,438	575
Stiff mud	422	1,861	1,027
Dry press	256	702	512

Here the order is found to be a little different than in the case of crushing strength, the stiff-mud brick showing the highest average, followed by the soft-mud and these by the dry-press brick.

Absorption. The percentage of absorption in the different bricks when tested by complete immersion for 48 hours ranged from 5.8 per cent to 34.30 per cent. Classified by kinds it was as follows:

Kind.	Minimum.	Maximum.	Average.
Soft mud	5.80	28.20	18.60
Stiff mud	13.05	24.30	20.26
Dry press	12.90	33.35	21.47

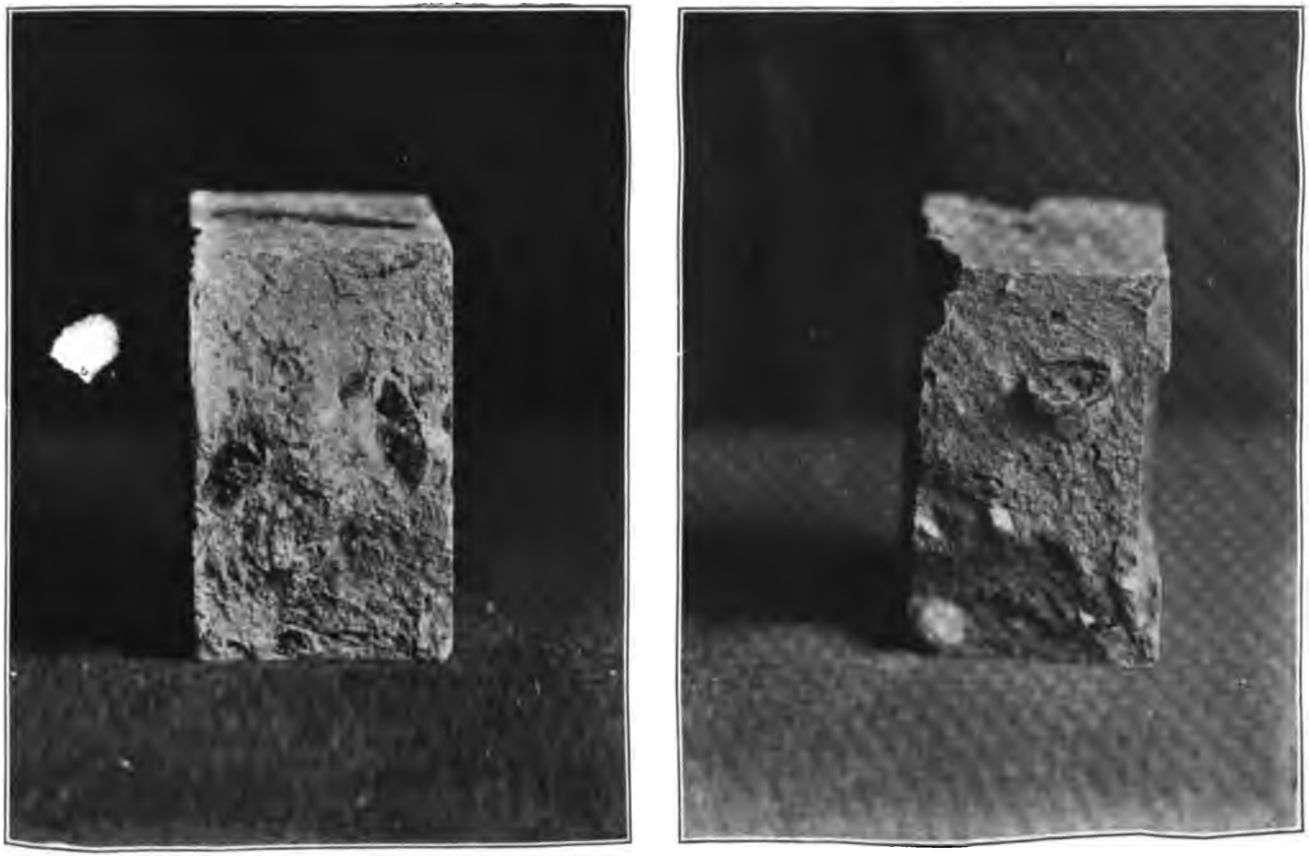
Here the order is again different. The soft-mud brick showing the minimum absorption as well as the lowest average absorption, while the stiff-mud showed the maximum absorption and nearly the highest average absorption. That of the stiff-mud and dry-press bricks is so high because they are made from calcareous clays.

CONCLUSIONS DEDUCIBLE FROM THE DIFFERENT TESTS.

1. The stiff-mud brick show the highest crushing strength because of the dense-burning character of the material used at most of the Wisconsin yards.

The minimum strength shown by the stiff-mud series falls considerably below the maximum crushing strength of either the soft-mud or dry-press bricks tested, so that the ranges of strengths shown by these classes overlap.

2. There is no direct relation between the crushing and



Half bricks, showing presence of lumps of unpugged clay and pebbles. These specimens had an abnormally low transverse strength.

transverse strength, a brick with a high crushing strength showing sometimes either a low or high transverse strength or vice versa. The following figures illustrate this:

Lab. No.	Kind.	Average crushing strength.	Average modulus of rupture.
220	Soft mud	1,192	526
114	Soft mud	4,572	569
22	Soft mud	3,036	1,063
137	Soft mud	5,796	1,062
99	Stiff mud	1,540	588
128	Stiff mud	2,708	550
207	Stiff mud	2,234	1,097
158	Stiff mud	4,996	1,090
99	Stiff mud	1,540	588
205A	Stiff mud	5,110	2,190
138	Soft mud	1,192	526
114	Soft mud	4,572	569

There are instances to be sure in which two bricks of nearly equal crushing strength will show closely similar transverse strengths. Thus

Lab. No.	Kind.	Average crushing strength.	Average modulus of rupture.
216	Stiff mud	6,230	964
202	Stiff mud	6,250	946

3. The percentage of absorption is not necessarily an index of either the crushing or transverse strength of the brick. This is well brought out by the following examples selected from the tables of tests.

Lab. No.	Kind.	Crushing strength.	Modulus of rupture.	Percentage absorption.
216	Stiff mud	6,230	964	19.6
205A	Stiff mud	5,110	2,190	7.6
99	Stiff mud	1,540	588	34.30
	Dry press	2,704	431	18.75
114	Soft mud	4,572	569	14.40
137	Soft mud	5,796	1,062	22.25
138	Soft mud	2,398	589	24.65

4. Harder burning will increase both the crushing and transverse strength thus:

Lab. No.	Kind.	Crushing strength.	Modulus of rupture.
206S	Dry press	993.3	256
206H	Dry press	1,996.6	469.6
28	Stiff mud	1,500	464.2
28A	Stiff mud	4,852.5	1,311.5

5. An interesting comparison is afforded by Nos. 143 and 90.

Lab. No.	Kind.	Crushing strength.	Modulus of rupture.	Per cent absorption.
143	Stiff mud	4596	749	20 55
90	Dry press	2704	431.8	18.75

Here we have two bricks, made from practically the same clay, and burned at the same cone but molded by different methods. If the dry-press brick were harder burned it would no doubt show up better. Additional examples are given below the first two being from Milwaukee, the other two from Racine.

Lab. No.	Kind.	Crushing strength.	Modulus of rupture.	Per cent absorption.
206H	Dry press	1,996.6	469.6	33.35
80	Stiff mud	3,380	1,034	20.55
202	Stiff mud	6,250	946.4	16.6
203	Soft mud	3,452	893.4	16.3

6. The transverse strength is often, and in fact almost invariably affected by the presence of pebbles, lumps of clay, or cavities, and whenever one of a series tested shows a low transverse break it can in nearly every instance be traced to this cause (Pl. XIX, Fig. 1 & 2).

7. The crushing strength is less easily affected by the flaws mentioned above.

REPORT OF PRACTICAL TESTS ON WISCONSIN CLAYS.

After the completion of the laboratory work on the Wisconsin clays, some large samples were collected from several localities and shipped to a brick works for a practical test.

The samples collected were:

1. Yellow, partially weathered Maquoketa shale from Leslie, Lafayette county.
2. Loess clay from Platteville, Grant county.
3. Brownish surface clay from Leslie, Lafayette county.
4. Shaly clay from the Richardson farm near Merrillan, Jackson county.
5. Shaly clay from the Davidson farm near Merrillan, Jackson county.
6. Red residual clay from Pittsville, Brown county.
7. Residual clay from Black River Falls Brick Works, northeast of Black River Falls, Jackson county.

These samples were collected by Dr. Weidman, of the Wisconsin Geological Survey, in the spring of 1905, and shipped to the Onondaga Vitrified Brick Co., at Warners, N. Y., where the tests were made under the supervision of J. H. Mead, Supt. The facts and opinions reported are largely his.

As a preliminary explanation it should be stated that the clays with one exception (No. 7) were prepared in a pugmill, and No. 1 in a dry pan. The molding was done in a side cut auger machine, and drying in tunnels constructed with flues underneath, and heated by fires built at the discharge end. The bricks were all burned in round downdraft kilns, the temperature unless otherwise stated being equivalent to the melting point of cone 1.

Details of tests.—Yellowish, slightly-weathered Maquoketa shale. This material after being ground up in a dry pan, pugged up nicely with water, and flowed easily through the die, requiring very little lubrication. It went through the drier in 24 hours, without showing any signs of cracking, and with the loss of 24 per cent of moisture. It had a linear air shrinkage of 3.2 per cent. When burned to cone 1, the brick were hard but the color poor. This is considered the least promising of the entire lot tested.

The same material was tempered thoroughly in the same manner and then put through a hollow brick die. It molded without any tendency to tear, and dried in 24 hours without cracking. On burning it yielded a good hard product, but not a very nice colored one. Color, however, is not a matter of great importance in fire-proofing.

Shale-Loess mixture. A mixture of the Leslie yellow Maquoketa shale, and the Platteville loess was next tried, 50 per cent of each being taken. This also worked well on the auger machine, dried in 24 hours without cracking, and lost 26 per cent of water.

At cone 1 the product was hard, and would probably vitrify under cone 2. The air shrinkage was 4.8 per cent and the fire-shrinkage 3.2 per cent making a total of 8 per cent. Mr. Mead believes that this sample will make a fair paving brick. Care should be taken however not to use any stony material.

A sample of Platteville Loess alone was next tried, and found to temper easily and flow readily through the die. It dried in 24 hours with a loss of 30 per cent moisture and without any injury to the brick. This burned to a good hard brick of excellent color, and mixed with some of the thoroughly weathered Maquoketa shale, might perhaps be employed for making a paving brick for light traffic. Its air shrinkage was 4.8 per cent and its fire shrinkage 4.7.

Sample from Richardson farm, Merrillan. The sample collected was much more sandy than that collected for the laboratory work, and was not altogether satisfactory. It contained many small lumps of soft sandstone which would have to be crushed. On account of its sandy character the material is lean, and very wearing on the die, but it dries easily, and burns to a hard product of excellent color.

Sample from Davidson farm, near Merrillan. This material was very similar to the preceding one but behaved better, flowing more smoothly through the die, and having greater plasticity. At the same time it is more stony than is desirable. It went through the driers in 24 hours without cracking and lost 28 per cent moisture. It burned to a hard red body, but needs thorough preparation before tempering.

Clay from Pittsville. This clay with proper pugging is well adapted to working in a stiff-mud machine, for it had good plasticity. It dries in 24 hours without trouble, losing 22 per cent moisture, and at cone 1 is nearly vitrified. Its air shrinkage was 4 per cent and its fire shrinkage 5 per cent. This clay burns a fine color and makes a good hard body.

Merrillan shaly clay. This is the material which has been used for common brick manufacture, and which Mr. Mead regards as the best perhaps of the entire series tested. It worked up well in the auger machine and dried without cracking, losing 22 per cent of moisture. It burned to an excellent hard product and at cone 2 has but 4.7 per cent absorption. Its air shrinkage was 3 per cent and fire shrinkage 4 per cent at cone 2.

The results obtained as given above may be summarized as follows:

All of the samples tested gave an excellent hard product at cone 1. For paving purposes it would be necessary to repress them. The majority should have thorough preparation to reduce or remove any stony matter that may be present. All show a low air and fire shrinkage. The Maquoketa shales are adapted to the manufacture of fire proofing.

CHAPTER VI.

FUTURE TENDENCY OF THE WISCONSIN CLAY-WORKING INDUSTRY.

A most pertinent question is "What can be expected of the Wisconsin clays in the future?"

Common brick will no doubt continue to be the most important product as they are now, but their production should grow steadily, and the successful growth of this branch of the industry, will depend largely on the establishment of large plants which can be operated economically and supplied by clays susceptible of rapid and easy treatment. It is probable that the estuarine clays will give better results than the lake clays.

Pressed brick are now made in limited quantities in Wisconsin, but since it has been pointed out that many of the red-burning and calcareous clays are adapted to this class of products, it is reasonable, to suppose that their manufacture will expand.

Drain tile and common red earthenware can easily be made from many of the smoother estuarine or lake clays, and even from the mellowed Maquoketa shale, but most of the other clays in the state are too gritty for this line of work.

Paving brick are not made at all in Wisconsin.

Some manufacturers of cream brick point to a few vitrified bricks obtained in the arches of their kilns as evidence that the clay is utilizable for paving products, but this is a mistake, as it would be impossible to bring a kiln full of such clay to vitrification. There are however, hard, dense-burning clays in the residual area which give great promise of producing a hard dense brick sufficiently durable for paving purposes in small cities, and the use of these clays from Merrillan, Halcyon, and Pittsville is suggested for this purpose.

Although the possibility of using certain clays for pavers seems good, the writer does not feel warranted in recommending any of the Wisconsin clays for sewer-pipe or stoneware manufacture.

Fire proofing and hollow brick could without doubt be made from the mellowed Maquoketa shales, and their location is such that they could be easily shipped to markets in both Wisconsin and Minnesota. To the south they would come into serious and probably unsuccessful competition with wares from other states. Nor should we lose sight of the fact that even in Wisconsin they must compete with material from Ohio and Illinois.

It is probable that the finer grained Wisconsin clays, as well as the slip clays will be in some demand in the future, the former by makers of art pottery, the latter by manufacturers of terra cotta, stoneware and perhaps even electrical porcelain.

We can therefore safely venture the statement that the outlook for the future is bright, and that there will be a steady increase in the annual production of clay products and raw clays in this state.

PART II.

REPORT ON THE MOLDING SANDS OF WISCONSIN.

BY HEINRICH RIES AND F. L. GALLUP.

PREFACE.

The following report on molding sands of Wisconsin has been prepared with the two fold purpose of giving information regarding the character of the molding sands obtained in the state of Wisconsin, and their points of resemblance or difference with those brought in from other states and of making some suggestions regarding the laboratory methods of investigation on this class of materials.

The field work on the report was done by the writer and his assistant, F. L. Gallup, during the summer of 1904, while the laboratory work was done mostly in the following winter. Mr. H. Leighton, has also rendered valuablè assistance, in making the porosity and specific gravity determinations.

REPORT ON THE MOLDING SANDS OF WISCONSIN.

INTRODUCTORY.

Under the term molding sand are included siliceous sandy materials employed for making either molds or cores, for use in casting iron, steel, bronze, brass, etc.

The materials employed vary in character from a loamy clay to a sand or even gravel, often but not always of highly siliceous character, the grade of the material employed depending on the size or character of the casting, the kind of metal, or the portion of the mold in which the sand is to be used.

For small castings, and for those on which it is desired to produce a smooth surface a fine sand is used, while for larger castings a coarser material is often employed.

Molding and core sands are not always used alone, and one or more grades are not infrequently mixed together, indeed the blending of molding sands is quite extensively practiced now both at the pit and at the foundry. Even this however does not always give a mixture of exactly correct physical properties, and so certain foreign substances such as cinders, ground coal, graphite, molasses, flour, stale beer, linseed oil or straw are sometimes added either to increase the bonding power or permeability of the material. It is therefore seen that a sand in its natural condition may not be deficient in certain qualities and yet by "doctoring" be greatly improved in quality.

The question may be reasonably asked whether it is possible to develop a set of standards to which molding sands used for different grades of work must conform. The problem is undoubtedly a difficult one, but still it may not prove as much so as one might expect.

If from a laboratory examination of a molding sand we can obtain at least some clues towards its possible applications, without having to go to the expense of time, labor, and material required for putting the sand through a practical test, much will be gained.

Previous work. A search through the literature reveals the fact that but little has been attempted in the physical and chemical investigation of molding sands, indeed the literature on the examination of molding sands is very meagre. Many books on foundry practice give but little attention to the value of a chemical analysis, although a few suggest that further chemical investigations would be desirable. A physical examination of the material is rarely referred to.

Perhaps the most important piece of work that has been done in the past, is that of Karmash and Sauerwein[*] made as long ago as 1862. They advocated strongly the value of a combined physical and chemical analysis as a result of their work on a series of some 16 sands from different part of Europe. These were analyzed chemically and the grains separated into three sizes, viz., coarse, medium and fine. As their papers are in more or less inaccessible publications it may be of interest to quote their results.

The sands examined by them were divided into two groups, viz., Lean and Fat sands.

A. Lean sands.

1. An Egyptian sand used for molding silver; a pure, coarse-grained sand, of low binding qualities.
2. Sand from Sebenstein bei Wiener Neu Stadt which for use is mixed with fat sand for the green-molding of iron. According to Sauerwein, its chemical composition was: Silica, 3.5 per cent.; $CaCO_3$, 54.6 per cent.; $MgCO_3$, 41.1 per cent.; $FeCO_3$, 1.1 per cent. The grains were of irregular shape and from $\frac{1}{20}$–$\frac{1}{4}$ m.m. in diameter, the finer grains predominating.

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[*] Ueber Formsand. Hannov. Mitth. (1862), p. 210; Berg u. Hüttm. Zeit. 1863, p. 137; Dingler Poly Jour. Vol. 168, p. 278; Deutsche-Technische Zeitung, Vol. 25, p. 229.

Sauerwein. Untersuchung von Formsand. Mitth. des Hannoverischen Gewerbevereins, 1862, p. 222.

3. A very lean sand from Neudorfel bei Wiener Neustadt which si mixed with Nos. 11 and 12. It contained 88,78 per cent. silica, 6.66 per cent. Fe_2O_3, 2.0 per cent. CaO, 2.6 per cent. MgO, and consisted of irregular sharp edged grains from $\frac{1}{12}$–$\frac{1}{4}$ and even $\frac{1}{2}$ m.m. diameter.
4. A sand from Shieffel used for iron molding. It contained 88.68 per cent. silica, 9.23 per cent. alumina, 3.42 per cent. iron oxide, .69 per cent. CaO. It is similar to the preceding in irregularity and size of grains; yet a part of them are more rounded and both contain but few fine grains.
5. Sand from Kernan for iron casting. Grains vary from $\frac{1}{60}$–$\frac{1}{4}$ mm., the largest being present only in small amounts.
6. Sand from Birmingham for iron work, very large visibly sharp-edged grains, from $\frac{1}{4}$ m.m.-$\frac{1}{60}$ m.m. in diameter. It contains 87.6 per cent. silica, 3.6 per cent. ferric oxide, 7.7 per cent. alumina, and 0.96 per cent. lime.
7. Sand from the Luneberger Iron Foundry, composed of very large grains, mostly $\frac{1}{3}$ m.m. also a moderately large number under $\frac{1}{30}$ m.m.. It contains 90.25 per cent. silica, 5.51 per cent. ferric oxide, 4.1 per cent. aluminum and 0.23 per cent. lime.

B. Fat Sands.

8. Screened sand from Benter Berg bei Hanover for brass and bronze molds; composed of irregularly rounded grains from $\frac{1}{60}$ to $\frac{1}{30}$ m.m., occasionally as large as $\frac{1}{20}$ m.m. It contains 92.21 per cent. silica, 3.26 per cent. ferric oxide, 4.0 per cent. alumina, 0.53 per cent. lime and a trace of MgO.
8. Sand from Verden for gold molding, has grains like the former, the largest part of them being under $\frac{1}{30}$ m.m. a few $\frac{1}{30}$ m.m. and occasionally $\frac{1}{10}$ m.m. It contains 97.46 per cent. silica, 8.00 per cent. ferric oxide, 3.7 per cent. silicate alumina, .84 per cent. lime and a trace of MgO.
10. Sand from Vienna used for the finest art work; grains mostly from $\frac{1}{60}$ to $\frac{1}{20}$ m.m. with a great many fine ones.
11. Sand from Vienna for fine iron molding containing very many grains being under $\frac{1}{60}$ m.m. the greatest in size being from $\frac{1}{20}$ to $\frac{1}{15}$ m.m. This is mixed with No. 2 for dry molding and with No. 3 for wet molding.
12. Very fat sand from Neudorfel near Wiener-Neustadt; indeed so fat that it is necessary to mix with No. 3 for dry molding, and for wet molding with large quantities of No. 3. It contains 55.85 per cent. silica, 15.74 per cent. alumina, 6.6 per cent. ferric oxide, 12.18 per cent. lime, 0.99 per cent. magnesium carbonate and 2.90 water. A few little grains $\frac{1}{30}$ m.m. and many at $\frac{1}{30}$ m.m.

13. Sand from Fontenay-aux-roses at Paris for fine bronze molding: grains from $\frac{1}{50}$ to $\frac{1}{12}$ m.m., the large grains being predominant. It contains 82 per cent silica, 7 per cent clay, 11 per cent ferric oxid; and a trace of lime.
14. Coarse sand for iron foundries containing however a considerable amount of close fine grains.
15. Fine sand for foundries, much like the preceding, with fewer large grains.

On mixing these sands with water, drying and making comparison as to their behaviour sands No. 1-7 were designated as lean sands, No. 8-15 as fat sands, this arrangement being according to their plasticity and binding qualities. No. 1, 2, 3, cannot be used alone for molding on account of their very slight cohesive qualities.

Table.

	Chemical Composition.			Mechanical Analysis.			
	No.	Per cent. silica.	Per cent. alumina.	Per cent. coarse sand.	Per cent. medium fine sand.	Per cent. fine sand.	Fine and medium fine together.
Lean sands.	1	....	....	100	....	....	....
	2	....	....	58	....	42	42
	3	....	....	93	4.2	2.8	7
	4	86.68	9.23	92.6	....	7.4	7.4
	5	....	....	82	2	16	18
	6	87.6	7.7	91	1.5	7.5	9
	7	90.25	4.1	85	2.5	12.5	15
Fat sands.	8	92.21	4	46.6	38	15.4	53.4
	9	87.46	3.7	34.6	34.6	30.8	65.4
	10	....	....	42	49	9	58
	11	....	....	24.5	32.4	43.1	75.5
	12	55.85	15.74	55	27	18	45
	13	82	7	82	0.8	17.2	18
	14	....	....	79	16	5	21
	15	....	....	59.4	26.8	13.8	40.6

¶According to Sauerwein the chemical and mechanical analysis of molding sands has given the above results. From the above table it is deduced that the "fatness" of a molding sand *is not always in proportion to its clay content* (No. 4 is leaner than 6 and 7, and contains more clay than 8, 9 and 13). Still the amount of fine parts contained exert a marked influence on the binding qualities, and the workability of the sands. (The lean sands contain 7-18 per cent., and the fat 18-75.5 per cent of fine material.)

This is practically the only examination of the combined physical and chemical properties which the authors have found a reference to. Even published chemical analyses are scarce as mentioned later.

This lack of previous laboratory investigations might lead some to suppose, that such methods were of little value, and even the foundryman in most cases looks on them with discouragement. Such action should however but serve as a stimulus to probe the matter more deeply, and not give up until it is definitely proven to be valueless.

In practical work the foundryman is accustomed to give a moist sand a preliminary examination by pressing it in his hand to see if the particles cohere, or to hold it between his hands and blow through it in order to test its permeability, and the acceptance or rejection of the sand sometimes hangs on this simple but insufficient test.

Even assuming however that laboratory standards for determining the uses of a sand are of little value, they might still have another application, viz. that of keeping check on the material being received from any one pit.

It is well known that the sand in any one deposit does not always run perfectly uniform in its character, or there may be carelessness in the sorting of the material from different beds in the bank. This may show up in the behavior of the material at the foundry. Now, if each shipment is examined, either physically or chemically, or both, variations can in most cases be detected, before any castings are spoiled. Of course, a certain amount of variation is permissible, and even unavoidable, but it should not be increased by careless mining or mixing of the raw materials at the pit.

The sands used for molding, can be separated into two groups, viz., those used for making the mold, into which the metal is poured, and those used for the core, which fills up hollow spaces of the pattern. They differ chiefly in their coarseness.

Requisite qualities of molding sands. Sands used for molding should possess the following requisites:

1. Proper texture.
2. Permeability.
3. As long a life as possible.
4. Moderate refractoriness.
5. Sufficient bonding power.

Texture. The texture of the sand or the percentage of grains of different sizes is determined by a sieve test, this being done by passing the sand through a series of sieves of decreasing mesh and noting the percentage which remains on each sieve.

The sands may be sieved either dry or wet. If the sizing is done on dry sand, it is found that some clay particles adhere to the sand grains, and therefore the percentage of the several sizes is greater than it should be.

A method used by Mr. W. G. Scott, of the J. I. Case Threshing Machine Co., of Racine, Wis., consists in placing ten grams of sand on the 100 mesh sieve, along with ten 7-16 in. steel ball-bearing balls, and shaking with a circular motion for one minute. The sand passing through is weighed and credited to the 100 mesh sieve. The sand remaining on the meshes of the sieve, together with the balls is emptied onto the 80 mesh sieve, the operation repeated, and so on up to the 20 mesh. With this method he claims less work is required and the results are more accurate.

The method adopted in analyzing the sands for this report was as follows:

Fifty grams of the sand were put in an eight ounce bottle, and the latter half filled with water. This mixture was then put in a shaker for four hours, after which it was washed through a set of 20, 40, 60, 80 and 100 mesh sieves. The sand retained on each was dried and weighed. That which passed through the 100 mesh was caught in a jar. When all the water and suspended matter had been run through the sieves the contents of the jar were stirred up, and after standing 45 seconds, the water with suspended clay and fine silt was decanted off. More water was added, the contents of the jar stirred and the decantation repeated. In this way two sizes were obtained. That which remained in suspension has been termed the clay and that which settled is indicated as 100+, and most of it is retainable on a 150 mesh sieve.

Some objection may be raised to shaking the material before sizing, because of its tendency to destroy some of the loosely cemented compound grains. It is probable, however, that in tamping the sand into the flask for casting, that many of these would be broken up. Those that are too hard to be thus crushed are likely also to resist disintegration in the shaker. It was found, however, that several of the sands analyzed contained compound grains on the 20, 40, and even 60 mesh sieves.

Plates XXIII to XXX represent photo-micrographs of the different sizes of several sands. In Plates XXIII-XXV, there are shown the 20, 40, 60, 80, 100 and 100+ sizes of a sand from Dead Lake Ridge, near Madison. All of these, except the first were photographed by transmitted light, and the first by reflected light. It will be noticed that the grains of these vary from round to angular and are mostly quartz. The opaque grains in Plates XXIV and XXV are quartz coated with limonite.

Plates XXVI to XXVIII represent the fractions of a fine core sand from Berlin all photographed by transmitted light, except Fig. 2, Plate XXIX, which was taken by reflected light, and is the same as Fig. 1, Plate XXVII. The enlargement in the former, however, is 7 diameters, and in the latter, 18 diameters.

Plate XXX, Figs. 1 and 2, represent the 20 and 40 mesh sizes respectively of a No. 4 Waterford sand from Valparaiso, Ind. The illustrations show that the grains are compound ones, being made up of small grains cemented together into compound ones of tubular or cylindrical shape. These tubes are found even in the 60 mesh sizes.

In the work for this report about fifty molding sands, mostly from Wisconsin were analyzed mechanically, and the limits of variation of the different sizes were as follows.

Size mesh.	I.	II.	III.
20	0. - 6	0. - .04	0. -12.76
40	.16- 9.08	.02- .90	.72-35.06
60	.34-42.00	.04- 2.3	19.96-56.24
80	.12-11.64	.02- 2.2	4.92-11.76
100	.18-39.16	.12- 1.84	3.24-30.06
100+	12.76-76.86	46.98-87.02	1.54-37.32
Clay	.36-35.52	11.92-52 64	. 4-18.26
Fineness	60.89-99.36	100.00-94.07	31.76-74.41

I. Sands for general work.

II. Brass sands.

III. Core sands.

An examination of the above figures shows that the fineness of each group varies in two cases at least, between rather wide limits, and as we might expect there is some overlap. That is to say, some of the sands used for general work are coarser than some of the sands used for cores. This is however to be expected. No one grade of sands can be used for all kinds and sizes of castings. Considering the average fineness of each group however, we see that the brass sands are the finest, the sands for general work the next, while the core sands average the coarsest.

In the accompanying table there are given the mechanical analyses of all the sands examined, together with their fineness.

Mechanical Analyses of Wisconsin Molding Sands.

Lab. No.	Locality.	On 20.	On 40.	On 60.	On 80.	On 100.	100+	Clay.	Total.	Ave. fineness
1	Berlin, Green Lake Co. fine core sand	.1	3.26	23.82	8.32	26.04	37.32	1.02	99.88	83
3	Dover	1.52	8.96	28.12	7.48	14.56	22.76	16.56	99.96	66
4	Pardeeville, Columbia Co...........	....	.36	23.76	9.50	35.76	30.22	.36	99.96	82
5	Pardeeville, Columbia Co...........	1.80	9.08	35.68	7.94	13 90	19.78	11.04	99.22	62
7	Berlin, Green Lake Co. for sm. c'st'g	....	.36	6.56	3.52	21.22	64.84	2.56	99.08	105
10	Pardeeville, Columbia Co...........	....	5.92	42.00	11.64	22.58	12.76	5.06	99.06	62
11	Fairwater, Fond du Lac Co.........	... .	4.86	34.46	8.06	29.38	22.58	.16	99.50	66
12	Fairwater, Fond du Lac Co.........	....	7.76	32.82	7.24	30.06	21.96	.32	100.16	66
13	Port Washington....................	....	.94	66.04	7.00	15 84	6.46	4.22	100.5	62
14	Milwaukee, Milwaukee Co..........	....	40.28	41.28	2.92	7.46	5.82	1.48	99.24	40
17	Berlin, Green Lake Co.	....	.76	3.74	1.78	10.44	62.96	20.06	99.74	125
19	Berlin, Green Lake Co. No. 3	....	1.76	10.44	4.50	14.52	45.42	22.64	99.28	106
20	Wheatland..........................	1.26	18.94	2.26	23.70	29.86	8.96	15.00	99.98	76
21	Altoona, Eau Claire Co....	.44	2.82	5.76	1.44	2.86	51.96	34.46	99.74	119
23	LaCrosse, LaCrosse Co.............	.54	7.72	13.00	1.94	8.34	49.76	18.10	99.40	86
24	Berlin, Green Lake Co...	....	1.46	9.78	3.52	14.86	47.48	22.86	99.96	103
25	Janesville, Rock Co. core sand.	....	4.00	28.72	8.48	22.54	21.22	14.84	99.82	78
26	Neenah, Winnebago Co	....	2.02	20.78	7.32	15.96	38.70	14.54	99.32	90
28	Berlin, Green Lake Co. No. 2......	....	.54	8.50	5.34	19.14	60.64	4.80	98.96	103
29	Racine, Racine Co.................	....	1.04	11.74	5.80	28 48	46.08	6.60	99.74	86
30	Janesville, R. Co. for cores, heavy cast	.4	16.54	56.24	5.60	5.20	2.60	13.34	99.92	40
32	Racine, Racine Co.........	....	.70	3.54	1.38	7.22	49.46	39.44	99.74	136
33	Racine, Racine Co..	....	.72	24.68	11.78	26.60	19.20	16.30	99.28	86
34	Neenah, Winnebago Co. brass sand .	....	.56	1.8	2.12	1.00	61.74	30.66	99.88	121
35	Neenah Winn. Co. sand for m. w. c.*	....	1.26	4.26	1.40	5.64	52.04	35.14	99.74	131
36	Menomonie, Dunn Co........... .	.54	2.74	5.44	.82	3.74	76.86	9.16	99.30	106
37	Marinette, Marinette Co............	2.08	3.68	12.06	4.26	9.22	39.14	29.10	99.54	92
39	Madison, Dane Co..................	10.66	21.98	43.86	6.50	9.02	4.12	3.66	99.76	39
41	Janesville, R. Co. for heavy work...	1.66	7.70	25 20	8.12	17.68	21.42	18.28	100.04	70
42	Superior, Douglas Co..............	12.76	35.06	40.56	5.72	3 24	1.54	.4	99.28	63
46	South Milwaukee, Milwaukee Co ...	6.90	11.44	27.76	8.76	14.10	12.47	18.52	99.95	54
50	Silverton sand, Kenosha Co....	1.32	14.02	28.68	5.62	10.24	14.12	25.02	99.02	63
58	Near Milwaukee....................	.1	7.10	62.02	10.05	10.54	6 92	2.32	100.05	53
65	Milwaukee, Milwaukee Co.....	3.56	5.47	28.41	10.61	27.76	22.75	tr.	98.55	62

*Medium weight casting.

Mechanical analyses of sands from other states.

Lab. No.	Locality.	On 20.	On 40.	On 60.	On 80.	On 100.	100+	Clay.	Total.	Average fineness
2	Wheaton, Ill	5.99	9.18	21.80	5.86	8.81	13.72	27.36	99.71	58
6	Massillon, Ohio	3.40	1.36	11.52	11.98	39.16	24.66	7.50	99.58	74
8	Zanesville, Ohio	.10	.28	.56	.14	.36	46.64	51.70	99.82	163
9	Albany, N. Y	....	.10	.20	.10	.20	71.22	28.16	99.98	143
15	Klondike, Mo	....	4.54	41.98	13.78	21.12	15.76	2.66	99.84	73
16	Zanesville, Ohio	....	.16	.34	.12	.18	74.82	24.16	99.78	140
22	A Mich. sand used at Grand Rapids, locality unknown	....	1.98	21.76	6.56	14.06	30.16	24.96	99.48	93
27	Rockton, Ill., upper bed	....	1.12	10.68	1.86	6.82	46.38	32.86	99.72	134
31	Rockton, Ill., lower bed	....	.90	2.30	.70	1.84	74.02	19.50	99.26	129
40	Kerrick, Minn	6.00	8.20	19.96	6.92	16.04	31.72	10.30	99.14	49
43	Newport, Ky., No. 5	....	.02	.04	.02	.14	77.54	22.12	99.88	140
44	Newport, Ky., No. 6	....	....	.06	.06	.62	87.02	11.92	99.68	132
45	Newport, Ky., No. 3	....	.06	.84	1.00	18.32	43.56	35.52	99.30	137
47	Indiana, No. 3	.06	.62	18.76	9.02	23.48	33.26	13.82	99.02	92
48	Indiana, No. 2	....	.94	18.18	8.54	29.96	34.22	7.94	99.78	88
49	Indiana, No. 1	.04	.66	11.42	8.12	20.64	35.40	23.42	99.70	105
51	St. James sand, St. Joe Co., Mich	....	.54	11.68	2.78	16.58	43.42	24.52	99.52	110
52	New Albany, Ind	....	.10	.20	.10	.24	76.60	22.80	100.04	139
53	Dyes Special, Ind	....	.06	.10	.04	.12	46.98	52.64	99.94	174
54	Waterford, Ill., No. 3	.04	.42	3.90	1.92	6.12	56.72	31.02	100.14	131
55	Waterford, Ill., No. 4	.04	.06	.12	.06	.12	80.12	19.22	99.74	137
56	Wanatah sand, Valparaiso, Ind	.26	3.56	26.08	10.06	17.70	15.10	27.12	99.98	83
57	B. Y., No. 1, Hamilton Co., Ohio	....	.10	.18	.06	.12	77.50	22.40	100.36	139

While it is possible to use these analyses for purposes of comparison it is sometimes rather slow work where a large series of analyses are being considered. If therefore we can devise some graphical method of showing the texture such comparisons can be more rapidly and satisfactorily made.

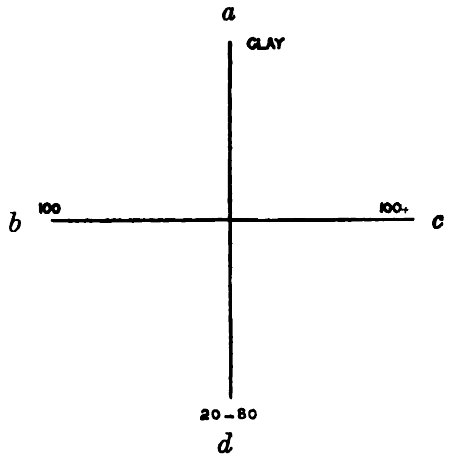

Fig. 6.

Fig. 6 represents the method adopted. On the four lines, *a, b, c, d,* there are laid off equal distances, corresponding to 100 per cent. On *a* the percentage of clay is laid off, on *b* the amount of 100, on *c* the percentage of 100+, and on *d* the combined percentage of 20, 40, 60, and 80 mesh grains. These last four are combined as they represent the coarse particles of the sand. Having laid off the proportionate distances on the four lines, the points are connected by straight lines, and the resulting figure shows at a glance the structure of the sand.

Plates XX, XXI, and XXII represent the texture of all the sands examined for this report. In the very fine ones it will be noticed that most of the figure lies above the horizontal line *bc*, while in the very coarse ones it lies below the horizontal.

For example, in Plate XX one can tell at a glance that Nos. 9 and 16 are practically identical, and that Nos. 32 and 27 are very closely alike.

Since the mechanical analysis is a rather detailed and lengthy mode of stating the texture of the sand, it is evident that if the fineness can be expressed by means of a single number it would also be much more convenient. Such a number must however represent the average fineness of the sand.

This average may be defined as the sum of all the quantities considered divided by the number of separate items.*

Now if in a sand we have

N_1 grains of size S_1
N_2 grains of size S_2
N_3 grains of size S_3
etc.

Then

$$\text{Average size of } S=\frac{N_1S_1+N_2S_2+N_3S_3+\ldots\ldots}{N_1+N_2+N_3+\ldots\ldots\ \ldots}$$

If the total number of grains is N then

$$N_1+N_2+N_3+\ldots\ldots\ldots\ldots=N.$$

And

$$S=\frac{N_1S_1+N_2S_2+N_3S_3+\ldots}{N}$$

or

$$\frac{N_1S_1}{N}+\frac{N_2S_2}{N}+\frac{N_3S_3}{N}+\ldots$$

But $\frac{N_1}{N}$ = the fractional part of the whole quantity which has a size S. So if the total number is taken as 100 (or proportional to 100)

$$\frac{N_1}{N}=\text{Per cent of size } S_1$$

and

$$\frac{N_2}{N}=\text{Per cent of size } S_2$$

In order to apply this formula to the mechanical analysis of a sand it is necessary to assume an average size for each mesh. In the case of the grains retained on the 20 mesh, it was assumed that they averaged 1/15 in., as few of them were much larger. This size would then be expressed decimally as .066.

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*The method of calculating the average fineness of a sand has been suggested to the writer by Professor J. S. Shearer of Cornell University.

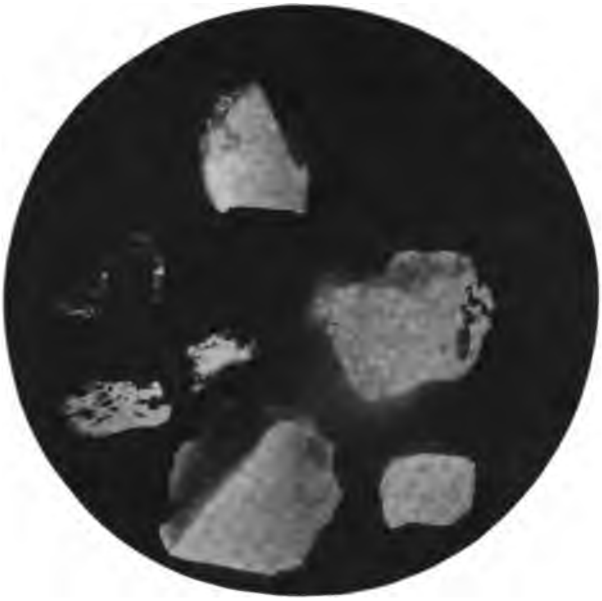

Fig. 1. Sand from near Madison, Wis. Particles retained on 20 mesh. × 7. By reflected light.

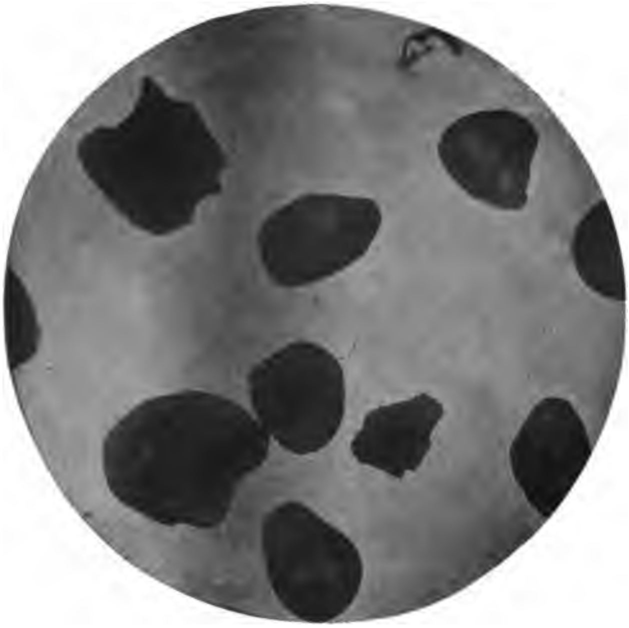

Fig. 2. Same locality. Grains retained on 40 mesh. × 18. By transmitted light.

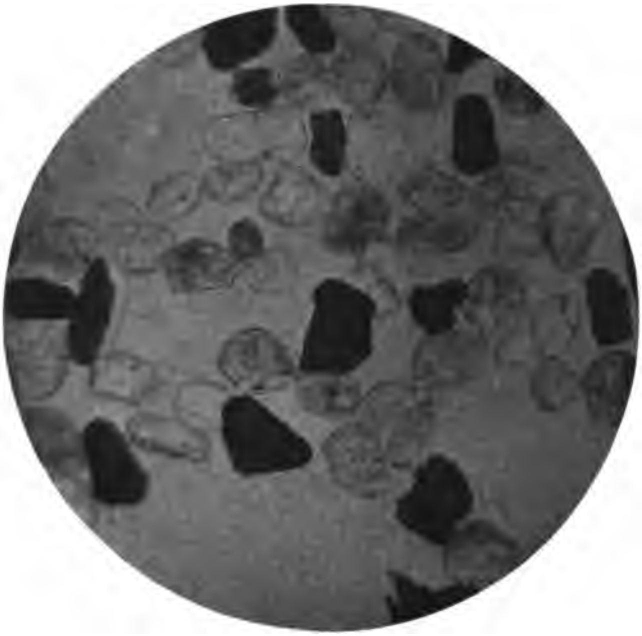

Fig. 1. Sand from near Madison, Wisconsin. Particles retained on 60 mesh. × 18. By transmitted light.

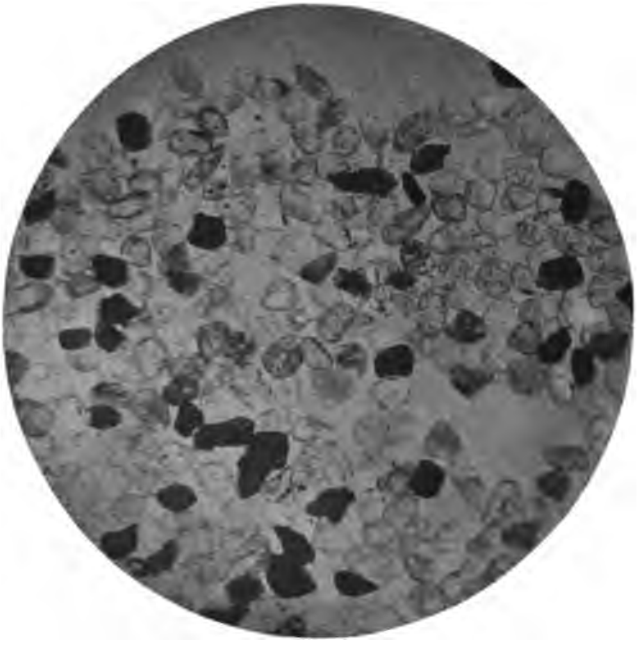

Fig. 2. Same locality. Particles retained on 80 mesh. × 18. By transmitted light.

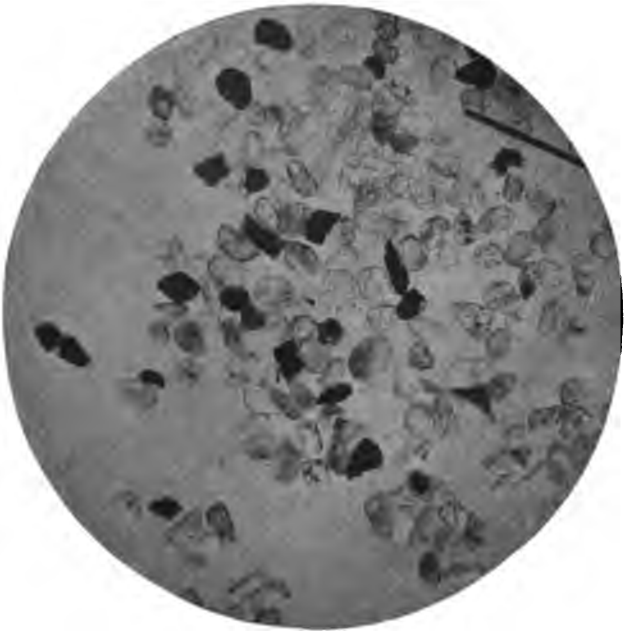

Fig. 1. Sand from near Madison, Wis. Particles retained on 100 mesh. × 18. By transmitted light.

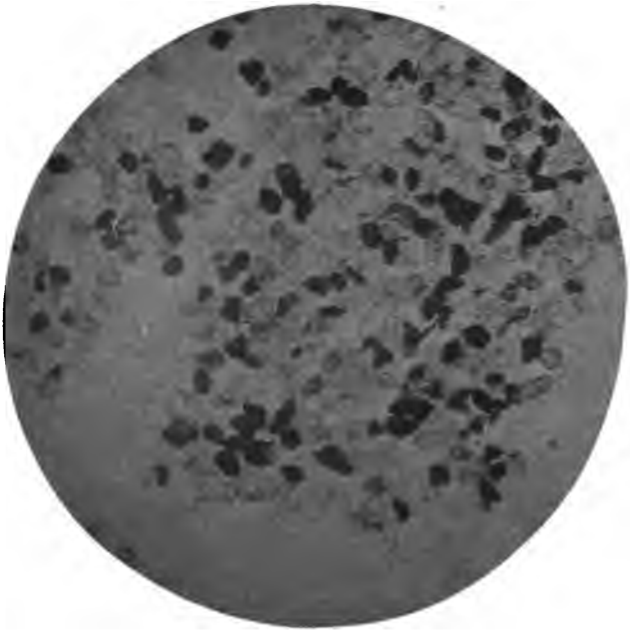

Fig. 2. Same locality. Particles retained on 150 mesh. × 18. By transmitted light.

Those which rested on the 40 mesh, might range from 1/20 to 1/40 inch, and their average was taken as approximately

$$\frac{\frac{1}{20}+\frac{1}{40}}{2} = .037.$$

and so on. The average size grain of the 100+size was taken as 1/150 in. or .008, while that of the silt and clay was assumed as .004.

As an example:

The mechanical analysis of one sand was:

Mesh.	Per cent.
20	.44
40	2.82
60	5.76
80	1.44
100	2.86
100 +	51.96
Clay	34.46
	99.94

$$\begin{array}{rcl}
.0044 \times .066 &=& .00029 \\
.0282 \times .037 &=& .00104 \\
.0576 \times .019 &=& .00109 \\
.0144 \times .013 &=& .00019 \\
.0286 \times .011 &=& .00031 \\
.5196 \times .008 &=& .00415 \\
.3446 \times .004 &=& .00137 \\
\hline
&& .00844 \text{ average grain size.}
\end{array}$$

$$\frac{1}{.00844} = 118 \text{ mesh.}$$

In other words, if all the grains in a given volume of the sand whose mechanical analysis is given above were reduced to a uniform size, they would pass through a 118 mesh. The average fineness of the sand is therefore given as 118.

It will be seen from an inspection of Plates XX to XXII that the average fineness of the sands examined ranged from 174 to 39.

PERMEABILITY AND POROSITY.

By the permeability of the sand is meant the property which it possesses of allowing liquids or gases to filter through it, and it depends therefore on the size of the pores.

By porosity is meant the volume of pore space between the grains.

These two properties are therefore not the same. A sand may contain a few large openings through which liquids or gases might easily escape, and yet have a small total pore space. On the other hand its total pore space might be large, but owing to the small size of the pores permeability by either gases or liquids becomes difficult.

The permeability of a sand might be influenced by three things, named in the order of their probable importance.

1. By the tightness of the packing.
2. By the size of the grains.
3. By the fluxing elements of the sand.

In discussing the effect of 2, two cases must be considered, (a) that of a sand whose grains are all of the same size, and (b) that of a sand whose grains are of unequal size.

If a given amount of sand is placed in a cylinder it will occupy a varying volume of space depending whether it is tightly or loosely pressed in, and the closeness of the packing may be increased by tapping the containing vessel. This gets the grains into their closest arrangement, producing the minimum pore space.

The amount of pore space produced in this manner however is dependent somewhat on the shape and size of the grains.

In order to make this clearer it is necessary to assume somewhat ideal conditions. An ideal sand would be one composed of spherical, uniformly sized grains, and the amount of porosity will be governed by the arrangement of the grains. Thus comparing Figs. 7a and b the most compact arrangement is that shown in Fig. 7b, in which each grain touches 12 other grains (King, U. S. Geol. Surv., 19th Ann. II, p. 306, et. seq)., and in this case the pore space would equal 25.95 per cent. If however each sphere touches only 6 others, as shown in Fig. 7a the maximum pore space is developed, and equals 47.64 per cent.

It makes no difference, what the diameter of the spheres is, provided they are all of the same size, the pore space will remain the same, with the same arrangement. With smaller spheres however, the pores will be smaller, and hence the permeability less.

Such ideal sands are practically unknown in nature, but fine-grained sands are more apt to approach theoretic porosities than the coarse grained ones.

If the sand is composed of grains of unequal size, then the small ones will fit in between the large ones, and the pore space will be still further reduced.

In nature the conditions are quite different, and the sands commonly found contain not only grains of irregular size but sometimes of angular character.

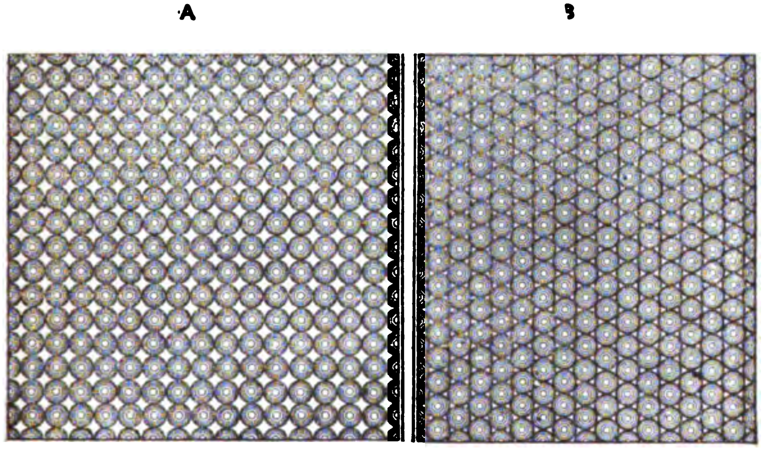

Fig. 7.—Maximum and minimum pore space of spherical soil grains. After King.

The investigations of King* have shown that the finer grained sands have a larger pore space than coarse grained ones, even though composed of approximately equisized grains, and that if the grains are angular, the pore space for any given size is increased, because angular particles will not pack so well. The minimum pore space was obtained by using two sands of rounded grains but different diameters, and mixed in equal parts.

In connection with grain size, there is probably one factor which is lost sight of, and that is the state of aggregation of the finer grains of the sand, whether they be silt, or clay. If these are separate, they will pack much closer, and tighter, than if cemented or bunched together in the form of compound grains. If in the latter condition the porosity of the mass would be larger, and the permeability also, than if the grains were separate, because the compound grains are themselves porous, (See Plate XXX, Fig. 1)· In the mechanical analysis of the sand, the grains undergo much rubbing, and these compound grains may therefore be destroyed.

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*19th Ann. Rept. U. S. G. S. II. p. 209-215.

The above brief discussion of the porosity of sands is not of purely theoretic value, but has several important practical bearings, for from it we see the means of increasing or decreasing the porosity of the sand. Thus tamping, because of forcing the grains together decreases the pore space, but even so theoretic conditions can rarely be reached.

Other things being equal, sands of vari-sized grains pack closer than those of equi-sized grains.

The decrease in permeability under increased tamping explains why some good sands behave badly, when packed too tightly, in the mold, refusing to allow the gases to escape, and causing blowholes.

The permeability of a sand is also influenced probably by the amount of water used in packing the sand. Foundrymen usually add a minimum quantity of water to the sand, in fact just enough to make it cohere sufficiently, it being claimed by some that an excess fills up the pores of the sand, and thereby decreases its permeability. While the addition of too much water may do this, the effect is probably an indirect one, and is due to the fact that wet sand will pack denser than dry sand. This closer packing will consequently decrease the pore space.

The relation between fluxing impurities and permeability is one which may show itself during the casting. If the clayey particles filling the interstices of the sand are sufficiently impure to fuse when heated by the molten metal, the coalescence of these in melting will have a tendency to close up the pores to some extent at least. For this reason partly a high percentage of fluxing impurities is found undesirable.

The proper permeability of a molding sand is a matter of vital importance, since it permits the gases to escape while the metal is being cast. These gases may be given off by the metal, or may be steam produced by the heat action on the moisture in the sand. A pathway must therefore be open for their escape, and if none is at hand blow holes are formed.

Since the degree of porosity of the sand is therefore an important matter, it becomes desirable to have some accurate means of measuring this if possible, and while several investigators have turned their attention to this problem, the results obtained have not been wholly satisfactory.

King (loc. cit.) for example showed from his experiments that the permeability as indicated by " the time necessary for 5000 cu. cm. of air to pass through a given sample holds no very apparent relation to the pore space which was found, except, indeed, that generally the larger the per cent. of pore space the slower the air was in passing through." In other words the finer the sand, the lower its permeability.

From this one might assume a general but not very close relation between pore space and permeability.

Since the measurement of the permeability of sands is more or less difficult, it is more desirable to determine the porosity, especially since this gives us an approximate gauge of the permeability of the material.

The pore space of a given volume of sand can be determined by the following formula.

$$\frac{Vd - W}{100\,Vd.}$$

in which:

V is volume of vessel in cubic centimeters.

d is specific gravity·

W is weight of the sand in grains.

The method employed consists in filling a cylindrical vessel of known capacity with the medium whose pore space is to be determined and then computing the pore space from the weight of the material and its specific gravity.

The best results according to King are obtained by allowing the sand to run into the receptacle in a fine steady stream. The closest packing and most uniform results being obtained by adding the material in small lots at a time, and gently tamping it with a broad flat faced pestle until the vessel was filled. After filling in this manner, the sides of the tube are gently jarred with light blows, until all reduction in volume ceases. In doing this it is necessary to hold the tube rigidly.

In the following table there is given the average fineness, specific gravity, and pore space in per cent. of the different sands tested, beginning with the brass sands and ending with the core sands.

Table showing the average fineness, specific gravity, and porosity of molding sands examined.

Lab. No.		Average fineness.	Specific gravity.	Porosity.
53	Dye's special, Newport, Ky.	174	2.50	42.45
8	Zanesville, O	163	2.72	44.70
9	Albany, N. Y	143	2,62	44.41
16	Zanesville, O	140	....	....
43	No. 5, Newport, Ky	140	2.60	40.11
52	No. 4, New Albany, Ind	139	2.66	41.31
57	No. 1 molding sand, Hamilton Co., O.	139	2.59	42.66
55	No. 4, Waterford, Ind	137	2.66	43.43
45	No. 3, Newport, Ky	137	2.61	43.09
32	Racine, Wis	136	2.65	44.14
27	Rockton, Ill	134	2.56	42.09
44	No. 6, Newport, Ky	132	2.64	43.26
54	No. 3, Waterford, Ill	131	2.62	40.43
35	Pendleton property, Neenah	131	2.59	44.62
31	Rockton, Ill	129	2.67	43.58
17	Fairwater (selected)	125	....	....
34	Neenah, brass sand	121	2.67	44.07
21	Altoona, near Eau Claire	119	2.67	46.83
51	St. Joe River, St. Joe Co., Mich	110	2.59	46.45
19	No. 3, Berlin	106	2.57	42.38
36	Menomonie	106	2.63	44.95
7	Berlin	105	....	....
49	No. 1, Indiana	105	2.59	45.18
28	No. 1, Berlin	103	2.60	39.4
24	Berlin	103	2.57	43.20
22	Garden City Sand Co	93	2.59	40.60
47	Indiana No. 3	92	2.60	42.63
37	Marinette	92	2.50	39.18
26	Neenah	90	2.61	44.76
48	Indiana No. 2	88	2.62	38.00
29	Racine	86	2.60	37.66
23	La Crosse	86	2.65	40.37
33	Racine	86	2.58	41.16
56	Wanatah sand, Valparaiso, Ind	83	2.51	43.70
1	Berlin	83	....	....
4	Pardeeville	82	....	....
25	Janesville	78	....	....

Table showing average fineness, specific gravity, and porosity of molding sands examined—Continued.

Lab. No.		Average fineness.	Specific gravity.	Porosity.
20	Wheatland, near Berlin....	76	2.51	47.26
6	Massillon, Ohio	74	2.58	42.76
15	Klondike, St. Charles Co., Mo.....................	73	2.59	34.98
3	Dover, Wis.................	72	....	....
41	Janesville	70	2.73	32.91
11	Fairwater (selected)........	68	2.61	32.00
12	Fairwater (run of bank)...	66	2.63	33.90
50	Silverton, KenoshaCo., Wis.	63	2.55	39.52
42	Superior	63	2.61	32.50
65	Milwaukee, Wis...........	62	2.64	37.47
5	Pardeeville................	62	....	....
10	Pardeeville................	62	....	....
13	Core sand, Pt. Washington	62	2.62	36.23
46	South Milwaukee..........	54	2.61	38.83
58	Near Milwaukee, Wis......	53	....	....
40	Kerrick, Minn.............	49	2.65	33.91
2	Wheaton, Ill	41	....	....
14	Ottawa, Ill................	40	2.67	34.77
30	Janesville	40	2.58	40.41
39	Madison..................	39	....	....

LIFE OF A SAND.

Most molding sands after being used once lose some of their desirable qualities, and after one or more heats become "dead" as the foundryman calls it. The length of a sand's life is therefore a matter of some importance. Some sands can be used but once, while others can be used over several times, with or without the admixture of some fresh sand. The deadness of the sand is no doubt due to its dehydration by the heat of the molten metal, its plasticity or bonding power being at the same time destroyed. The water of hydration thus lost comes largely from the clay and we may perhaps inquire with reason, whether clayey sands become dead sooner than those containing low clay contents.

The amount of sands thus destroyed in casting will be a layer of variable thickness next to the metal. With small castings this will be but a fraction of an inch, and will be correspondingly greater with large ones.

REFRACTORINESS.

A molding sand should be sufficiently refractory to prevent its fusing completely when in contact with the molten metal. For this reason highly siliceous sands are the most desirable, at the same time a very high percentage of silica is only to be gained at the expense of alumina or clayey matter and a consequent loss in cohesiveness or bonding power. The effect of the chemical composition on the refractoriness of the sand is discussed under the chemical analyses of molding sands.

There is no standard laboratory test for determining the refractoriness of a molding sand. Perhaps the best would be to make a flask of the sand to be tested and pour into this an iron of known composition so that its effect on the sand could be determined. Means not being at hand to carry out this test, the next best plan seems to be to mold the sand into cubes and heat these rapidly in a furnace.

The following table contains the results of a number of tests of this sort made by C. W. Hord and kindly placed at the writer's disposal. The cubes were made by mixing the sand up with sufficient water to make the grains cohere, and then forcing the sand into a wooden mold by blows from a 9¾ lb. lead rammer, with a drop of four inches. These cubes were then heated in a gas furnace to a temperature of Cone 6 (fusion point approximately 2282° F., or 1250° C., the time required for burning being from 45 minutes to 1 hour. After burning the cubes were weighed, soaked in water for 48 hours and weighed again the increase in weight indicating the amount of water absorbed and being therefore an approximate index of the porosity after burning. Of course it will be easily seen that any shrinkage of the mass, or fusion of the particles will serve to close up the pores and decrease the absorption. Since it was recognized that the amount of tamping the sand received, and the quantity of water used might affect the density, four mixtures were made up as follows:

1. Water taken 6.6 per cent., number of blows, 3.
2. Water taken 6.6 per cent., number of blows, 9.
3. Water taken 13.2 per cent., number of blows,3.
4. Water taken 13.2 per cent., number of blows, 9.

The results obtained are given on pp. 218-219.

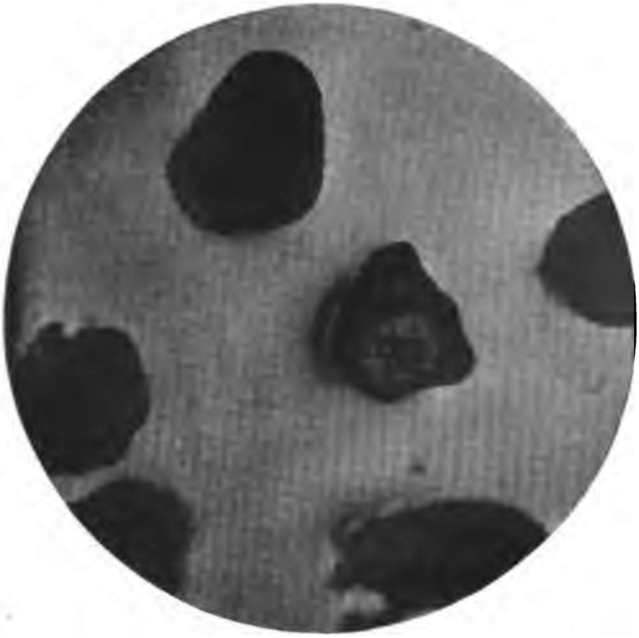

Fig. 1. Fine core sand, Berlin, Wis. Particles retained on 20 mesh. × 18. By transmitted light.

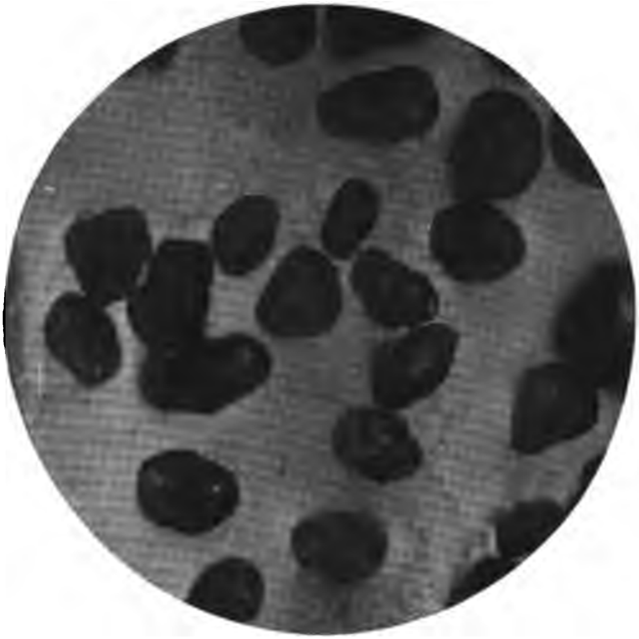

Fig. 2. Same locality. Grains retained on 40 mesh. × 18. By transmitted light.

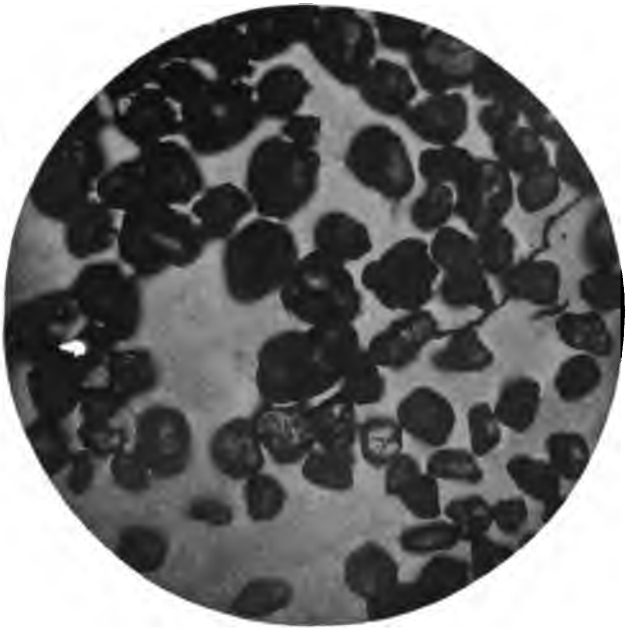

Fig. 1. Fine core sand from Berlin. Particles retained on 60 mesh. × 18. By transmitted light.

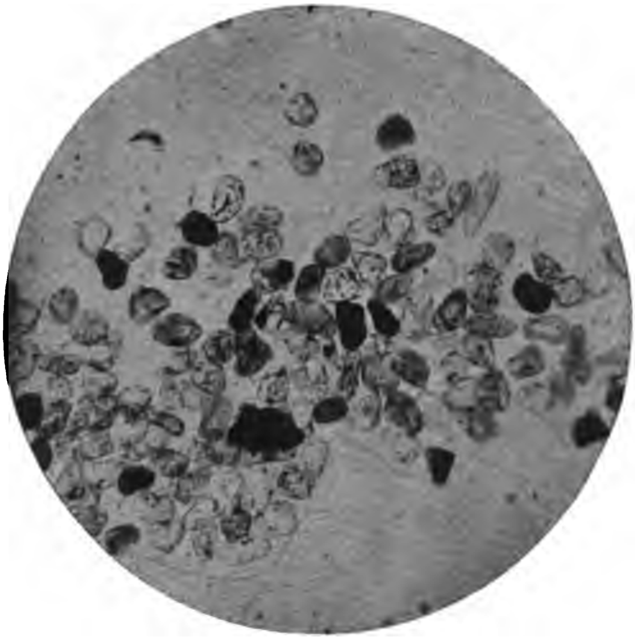

Fig. 2. Same locality. Grains retained on 80 mesh. × 18. By transmitted light.

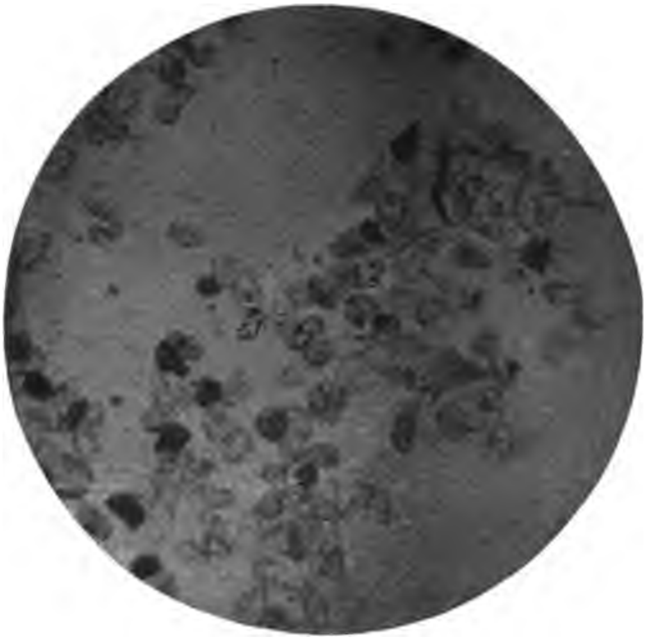

Fig. 1. Fine core sand, Berlin, Wis. Grains retained on 100 mesh. × 18. By transmitted light.

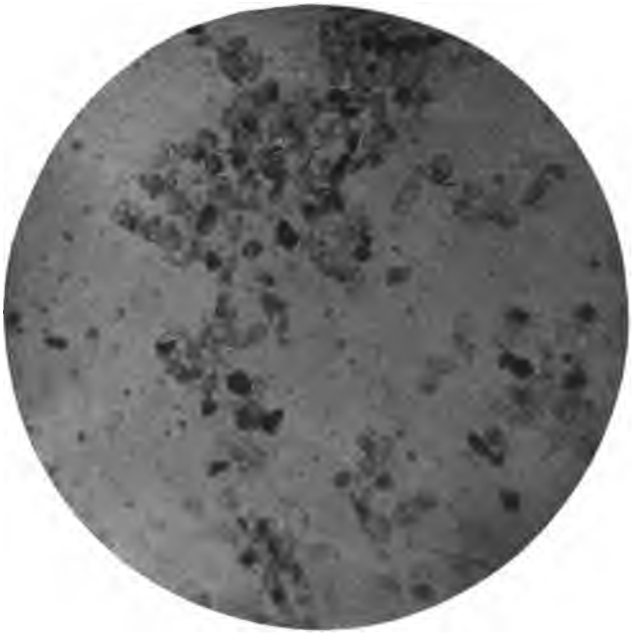

Fig. 2. Same locality. Grains retained on 150 mesh. × 18. By transmitted light.

The figures given in the table are not without interest. If we examine the 1st, 2nd, and 3d. columns of figures, we find that in every case, more pounding or a greater amount of water for mixing, tended to decrease the porosity as evidenced by the absorption figures, but that the use of a higher percentage of water, seemed to reduce the porosity more than an increased number of blows, even though the former was only doubled while the latter was tripled.

One is somewhat puzzled to find the causes which govern the degree of porosity of the sand after burning. Taking the first absorption number of each set, we find that it ranges from 30 per cent. down to 2.8 per cent. This figure does not seem to stand in any direct relation to the average fineness or porosity of the green sand, neither does it appear to be directly related to the clay percentage.

It would seem that the porosity after burning is due to three causes, viz., amount of clay particles, an evenly proportioned number of the different sized grains, and the amount of fluxing impurities in the fine particles. That is to say, with a number of different sized particles there will be less porosity in the mass, than if most of the particles were of one size, because this enables them to flux together more readily because of closer packing.

BONDING POWER OR TENSILE STRENGTH.

Sands used for molding should possess sufficient tensile strength or bonding power to make the grains cohere after the flask in which they are tamped is removed, and also for the purpose of resisting the pressure of the molten metal in the mold, or its corrasive action while being poured into the mold. Pure sand, has little or no tensile strength, unless very finegrained when it may cohere slightly if moistened and packed, clay alone has a comparatively high strength, and the amount of bond will depend partly on the fineness of the sand, and partly on the amount of clayey matter in it. The tensile strength of the molding sand will be likewise somewhat affected by the amount of moisture in it ,moist sandc ohering more strongly than dry sand.

Refractoriness tests of molding sands.

Locality and uses.	No. of 4 inch blows with hammer	Per ct. water taken.	Per ct. absorption.	Approx. fire shrink.	On 20 mesh.	On 40 mesh.	On 60 mesh.	On 80 mesh.	On 100 mesh.	100 +.	Clay.	Aver. fineness.	Pr ct. porosity.
				Per ct.									
Zanesville, O. Used for heavy malleable iron and other large castings.	3	6.6	23	....	1.32	11.18	33.40	4.29	6.64	9.84	32.82	67.3	35
	9	6.6	17	5									
	3	13.2	13	....									
	9	13.2	8	0									
Zanesville, O. Brass sand.	3	6.6	30	....	.02	.45	2.02	.42	.86	80.36	15.06	125.9	43
	9	6.6	25	1									
	3	13.2	25	2									
	9	13.2	22	1									
Zanesville, O. Heavy sand.	3	6.6	24	....	.19	.60	8.08	4.75	12.70	53.73	19.12	111	37
	9	6.6	20	2									
	3	23.10	16	....									
	9	23.10	11	2									
Cincinnati, O. Fine brass sand.	3	6.6	18	....	.08	.12	.18	.10	.28	77.88	20.28	133	45
	9	6.6	12	7½									
	3	13.2	9	....									
	9	13.2	7	3									
Fine sand. Whitehead Bros.	3	6.6	2.8	10	.10	.14	.98	.12	1.18	64.94	30.76	146	42
	9	6.6	1.7	10									
	3	13.2	.08	7½									
	9	13.2	.02	10									

Medium grained sand. Whitehead Bros.	3	6.6	16	0	.94	3.28	19.38	4.42	9.04	49.84	12.18	86	39
	9	6.6	15	0									
	3	13.2	13	0									
	9	13.2	8	0									
Coarse sand. Whitehead Bros.	3	6.6	18	0	8.66	10.24	32.58	4.12	8.38	23.10	11.70	51.8	34
	9	6.6	12	0									
	3	13.2	11	0									
	9	13.2	5	0									
Fine sand. Raritan Ridge Clay Co., Metuchen.N.J.	3	6.6	27	0	3.44	12.40	25.84	6.60	19.12	24.50	7.28	59	39
	9	6.6	Crum	bled									
	3	13.2	24	0									
	9	13.2	22	0									
Coarse sand. Same firm.	3	6.6	19	....	24.2	22.50	14.36	2.78	4.24	11.19	19.20	66.1	33
	9	6.6	16	0									
	3	13.2	8.4	0									
	9	13.2	8.	0									
Medium sand. Same firm.	3	6.6	....	0	3.96	7.50	13.48	6.34	15.30	31.68	21.	79.5	39
	9	6.6	31	0									
	3	13.2	16	0									
	9	13.2	9	0									
Molasses sand. Florida Grove, N. J.	3	6.6	Crum	bled	8.52	40.50	16.34	1.50	2.62	7.44	20.74	......	40
	9	6.6	22	0									
	3	13.2	16	0									
	9	13.2	3	0									

The moisture content should not be in excess however, otherwise the sand will pack too densely. With clay, the amount of coherence will not be seriously influenced by the amount of moisture, since the particles in drying shrink together, but with sand or even loamy sand when the shrinkage is exceedingly slight or even zero, there is no drawing together of the grains in drying, and therefore the presence of moisture aids the bonding power; pressure may likewise increase it.

Where the mold is of complex design it is obvious that a stronger bond is necessary than for simple patterns. In such cases it may become necessary to increase the bond by the addition of some binding material.

THE CHEMICAL ANALYSIS OF MOLDING SANDS.

A difference of opinion appears to exist regarding the value of a chemical analysis of molding sands, and but few such analyses are on record. Those which have been published usually show a high percentage of silica and consequently it has sometimes been assumed that all molding sands are highly siliceous. That this is not so in all cases is shown by the few analyses which were made for this bulletin.

While the physical properties of molding sands are of preeminent importance, the chemical properties of the sand should not be neglected, especially since the chemical analysis may show the presence of objectionable elements, such as fluxing impurities, which are at times present in surprisingly large quantities.

Much the same interpretations can be made from a molding sand analysis as from that of a clay.

A high silica percentage indicates a large amount of quartz, while from the alumina and chemically combined water, we can make some estimate of the amount of clay present. The analysis will furthermore indicate the amount of fluxing impurities, such as iron, lime, magnesia, and alkalies which the sand contains.

In most published analyses the percentage of the last four is very low, but in some of the Wisconsin sands the lime and even magnesia occur in appreciable quantities.

The allowable limits of the different ingredients, are not as a rule given.

Bolland* states regarding the chemical composition of molding sand that "3% of metallic oxides in sand seriously diminishes its refractory qualities and 1% of lime measurably lessens its value as a good molding sand, as the carbonate is acted upon by the intense heat and gives off CO_2 which disturbs the face of the mold during its escape, causing honey-combed and rough surfaces on the casting. Caustic lime will cause a slag on the surface of the casting.

Sands which contain the largest percentage of silica, from 1–3 per cent magnesia, with as much alumina as will impart cohesiveness and plasticity are under almost all circumstances the best for facing sand. Lime should not be present in even the smallest proportions."

In specifications for molding sand, prepared by Mr. Scott of the Case Threshing Machine Co., Racine, Wis., the following statements are made, regarding the chemical composition of sands for molds and cores.

Molding sand. "Molding sand for iron work generally contains from 75.00 to 85.00 per cent. of silica, 5.00 to 13.00 per cent. of alumina, usually less than 2.50 per cent. of lime and magnesia, not over .75 per cent. of fixed alkali (soda and potash), generally less than 5.00 per cent of iron oxide, and seldom more than 4.00 per cent. of combined water."

"Sand for brass molding may contain a much higher percentage of iron and lime without doing any particular harm."

"All molding sands usually contain some organic matter, generally present in the form of small roots or as decomposed vegetable matter.†

"Carbonate of lime must not exceed 1.50 per cent in an iron-molding sand, and should not exceed 2.25 per cent in a brass sand.

"Iron oxide must not exceed 5.50 per cent. in the iron-molding sand, or 7.00 per cent. in a brass sand.

"Organic matter must not exceed 1.00 per cent. Clay and silt are objectionable, consequently any sand showing on analysis more than 13.00 per cent alumina is rejected."

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*Encyclopedia of Foundry.

†The amount present is generally so small that it can be neglected.

I. Sand from foundry of Freund at Charlottenberg .. II. Bronze sand, used at Paris .... III. Sand from Manchester .... IV. Sand from Lagua foundry at Stromberg	Kampmann Ann. des M's Ser. 4, Vol. VIII, p. 689, 1895.
V. Fine sand .... VI. Sand for medium weight castings. .... VII. Coarse sand for heavy castings .... VIII. Sand for heavy machinery in dry sand molds......	W. Ferguson, Iron Age, Vol. LX, p. 16 1897.

These analyses, it will be observed all show a high percentage of silica, since most of the sands used are of siliceous character. They do not however show the variations in composition existing in molding sands.

These are well brought out by a few analyses made for this report.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
Lab. No............	(25)	(27)	(28)	(31)	(34)	(36)	(42)	(9)
Silica (SiO_2)........	88.52	79.41	90.68	57.63	44.24	80.35	87.47	79.61
Alumina (Al_2O_3) ...	5.63	12.47	5.95	10.03	11.89	11.57	6.59	11.21
Ferric oxide(Fe_2O_3).	.88	.80	.48	.88	1.44	1.04	.80	2.48
Lime (CaO).........	1.20	.99	.69	11.16	13.71	1.33	1.18	.74
Magnesia (MgO)....	.83	.31	.44	5.63	5.90	.66	1.10	1.07
Ignition............	2.65	3.96	1.05	14.66	18.49	2.45	.60	2.65
Alkalies(Na_2O,K_2O)	......	Not	deter	mined				
Total	99.71	98.44	99.29	99.99	95.67	97.40	97.74	97.76

I. Core sand, Miltmore quarry, Janesville, Wis.
II. Upper bed, Rockton, Ill.
III. No. 2 sand. White and Traugott Pit, Berlin, Wis.
IV. Lower bed, Rockton, Ill.
V. Brass sand, Pendleton Pit, Neenah, Wis.
VI. Sand from pit of Menomonie Hydraulic Pressed Brick Co., Menomonie, Wis.
VII. Lake sand, Superior, Wis.
VIII. Fine sand, Albany, N. Y.
Analyses I-II by F. L. Gallup.
Nos. III-VIII by H. Leighton.

Two of these analyses, Nos. 4 and 5, show a very low silica content, and therefore show a correspondingly higher percentage of fluxing impurities, especially lime. Nos. 2 and 4, are of interest as showing the great difference in composition which

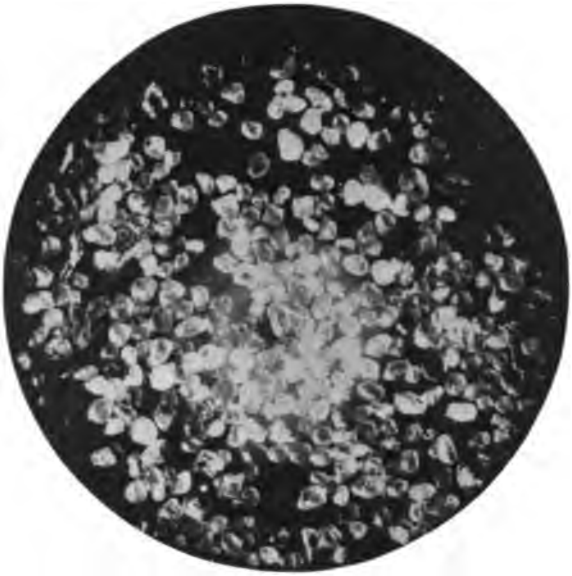


Fig. 1. Fine core sand, Berlin, Wis. Grains retained on 60 mesh. × 7. By reflected light.

Fig. 2. Same locality, clay grains. × 18. By transmitted light.

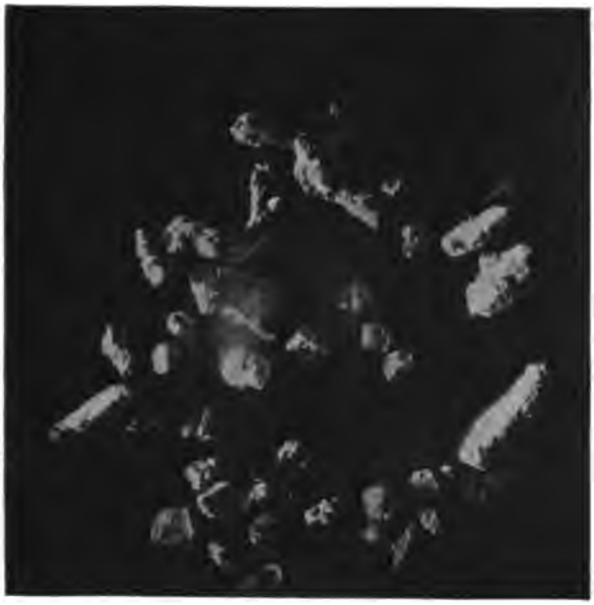


Fig. 2. Grains of same retained on 40 mesh sieve. × 7. By reflected light.

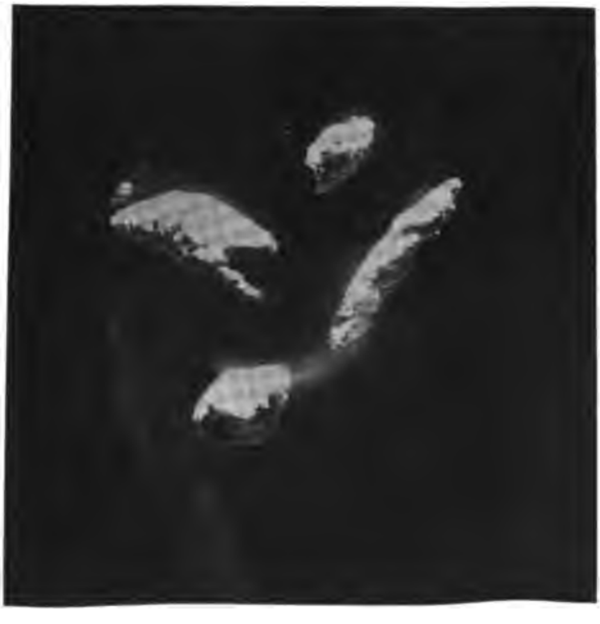


Fig. 1 Sand tubes, retained on 20 mesh. × 7. No. 4 Waterford sand, Valparaiso Ind. By reflected light

may exist in different beds of the same bank. The others are mostly of siliceous character.

If the main use of a chemical analysis of a sand is to indicate the amount of fluxes and silica which the material contains, there is some doubt in the writer's mind, whether an analysis of the sand in bulk is what is needed. Such an expression of the composition does not show us in what condition the fluxes exist, that is to say, whether they occur in the coarsest or finest particles. If in the former their fluxing effect will be less active than if in the latter.

In most sands the fluxes are probably contained largely in the fine particles, especially if the deposits are of sedimentary character, for in these the coarse grains would represent the more indestructible mineral grains, such as quartz.

If however the material is a residual sand, and some molding sands are, then the fluxes might exist wholly or in part in larger grains of partially decomposed silicate minerals.

In order to illustrate the uneven distribution of fluxing materials, a partial analysis was made of the several sizes of grains in a No. 2 sand from Berlin, Wis., with the following results.

Size	60	80	100	100+	Clay.
Silica (SiO_2)	95.92	94.35	94.66	91.06	61.54
Alumina (Al_2O_3)	1.29	1.47	1.47	4.57	23.16
Ferric oxide (Fe_2O_3)	.56	.56	.40	.80	1.60
Lime (CaO)	.10	.04	34	.72	1.37
MgO & Alk. By. diff	2.13	3.58	3.13	2.85	4.43
Loss, ignition		Undetermined.			7.90
Total	100.00	100.00	100.00	100.00	100.00

Here we see that the finer particles are much less siliceous, more highly aluminous and carry a higher percentage of fluxes than the other sizes.

MINERALOGICAL COMPOSITION.

The mineralogical composition of the Wisconsin molding sands as well as that from a number of other localities is remarkably monotonous. A microscopic examination was made of all different sizes obtained in the sieve tests, and in nearly all with the exception of the clay the predominating mineral was quartz. This sometimes formed 90 per cent of all the grains in the sample. The grains are mostly rounded, and while those on the 20 and 40 mesh were often quite free from iron the smaller sizes often exhibited an abundant stain of limonite. Compound grains of quartz sand cemented by limonite were by no means uncommon. In addition to quartz, feldspar mica and even garnet were sometimes noted. Several sands as No. 55, contained little sand tubes in the 20, 40, and even 60 mesh sizes. These were apparently cemented by calcium carbonate.

In a few, the grains retained on the 20 mesh were not simple minerals but small fragments of rock, such as sandstone, quartzite, gneiss, schist, and limestone. All of these were invariably angular. None of the sizes under 20 mesh, could be said to be markedly angular although a few were subangular.

After examining this large number of samples under the microscope, one is forced to the conclusion that very little is to be gained from such an examination.

MODE OF OCCURRENCE OF MOLDING SANDS.

Molding sands may be either of residual or sedimentary character. To the first class belong those sands formed by the disintegration of the rock in situ, while the second includes those formed by the deposition of sandy or loamy material in water.

Residual sands may be derived from either crystalline or sedimentary rocks. If from the former their particles are likely to be angular; if from the latter the grains would tend to show a rounded form. No deposits of the first type of residuals are known in Wisconsin, although they might possibly exist, but examples of the second type are not uncommon. The Potsdam sandstone in many localities is so soft that it weathers easily to a mass of highly siliceous sand, which is composed almost entirely of rounded quartz grains. At many localities where the stone is exposed it is so soft that very little power would be required to disintegrate it completely if it is not already in that condition.

Sedimentary sands and loams are much more abundant and form the main type of material obtained in the state. These sands represent sediments laid down by water in lakes, along the flood plains of rivers, or have been deposited by streams flowing from the margin of the ice sheet during the glacial period. Some of those found in the belt bordering the Great Lakes have been formed in the waters of these during a period when they covered a greater territory than they do now.

The coarseness of the material laid down will increase with the velocity of the current which deposited it, and variations in the velocity over any one area, will result in the accumulation of layers of different texture. Sand deposits not infrequently show both horizontal and vertical variation, and in the examination of a sand bank, care should be taken to ascertain whether there is a sufficient quantity of the desired grade present. Some deposits though otherwise good, are spoiled by the presence of clay lumps scattered through them.

In many areas, especially along the lakes, dune sands cover tracts of considerable extent. The materials forming these dunes are usually of little value for molds, because they commonly lack even the small amount of clayey material necessary to bond the sand when moist. They are however used for cores, but then require an artificial binder.

In many districts three or four different grades of sand are obtained from separate pits all lying within a few rods of each other. Or again one bed may persist over a large area, with a thickness of not more than two feet, and underlain by an equally persistent bed of totally different grade or texture.

Owing to the complexity of the glacial deposits in which most of the Wisconsin molding sands occur, it is difficult to lay down any rules that will guide the layman in his search for them. If however laboratory methods prove to be of practical value it becomes a comparatively easy matter to collect samples from all available localities and put them through a rapid preliminary examination.

DETAILED ACCOUNT OF THE SANDS EXAMINED.

Introductory. There are about 150 foundries in operation in Wisconsin, some of which are of large size, and consequently consume large quantities of molding sand annually.

Nearly all of these use Wisconsin molding sands wholly or in part, but a few obtain their supply entirely from other states.

In order to ascertain to what extent Wisconsin sands were used, and what advantages lay in the use, in part at least, of sands from other states, a letter requesting information was addressed to the different foundries in the state. Replies were received from 110 firms, out of a total of about 150, and a summarized statement of the replies received is not without interest.

The value of the molding sand purchased by 110 firms during the year 1904, amounted to $89,882.00. Of this amount $44,113.00 was reported as Wisconsin molding sand and $45,769.00 as sand obtained from other states.

The firms that pronounced the Wisconsin sands to be satisfactory included manufacturers of malleable iron castings, agricultural machinery, steam shovels, dredges, wrecking machinery, dairy machinery, horse shoes, saw mill machinery, gas engines, letter presses, coarse hardware, etc.

Those objecting to Wisconsin sand, included producers of cooking ranges, light dairy machinery, fine agricultural implements, office and school fixtures, farm machinery, grey iron and crucible steel castings, and fine hardware.

As the details of the replies received from the various firms are to be regarded as confidential, only general statements can be made here.

A careful study of the replies received seems to indicate that the sands obtained from other states belong chiefly to the finer grades, and inspection of the table on p. 206, will show that nearly all of the sands obtained from other states have a finer average grain than the Wisconsin sands now in use, and are therefore better adapted for finer grades of work. In some instances though, the Wisconsin sands are as fine grained as some of those obtained from other states.

Instances were found of two factories at different localities making the same line of wares, but one using Wisconsin sands with good results, and the other pronouncing them worthless. In such cases it was found that both had not tried the same Wisconsin sand, but purchased their supplies from different locations.

Many foundrymen seemed to be unfamiliar with all the Wisconsin sources of supply, and it is hoped that this bulletin may prove of use in bringing the various deposits to their attention.

Practically all the core sand used by Wisconsin foundrymen is obtained within the state.

While other states, some as far distant as New York are supplying the Wisconsin foundries with most of their fine sand, there seems to be no good reason why, with the variety of glacial sands and lake sands which occur within the state, the higher grades of sand should not be found.

The Loess area of western Wisconsin, underlain by an extensive sheet of silt and clay silt, seems one of the most favorable fields for finding fine grained molding sand, and the sample tested from Menomonie is the nearest to this type seen in the state.

SANDS OBTAINED FROM THE CENTRAL STATES.

These represent types of molding sands, mostly of fine-grained character, many of which are used in Wisconsin. The following descriptions are based partly on the laboratory examination and partly on replies received to inquiries.

Illinois.

Waterford.—Two samples of this were obtained from the Newport Sand Company of Newport, Ky. The first of these, known as No. 3 grade (Lab. No. 54) is used for malleable iron castings, agricultural implements, etc.

Its mechanical composition is

Mesh.	Per cent. retained.
20	.04
40	.42
60	3.90
80	1.92
100	6.12
100+	56.72
Clay	31.02
Total	100.14

Fineness, 131; Specific gravity, 2.62; Porosity, 40.43.

The other sample known as No. 4 grade (Lab. No. 55), is finer grained and claimed to be excellently adapted for castings of malleable and gray iron and brass.

Its mechanical analysis gave:

Mesh.	Per cent retained.
20	.04
40	.06
60	.12
80	.06
100	.12
100+	80.12
Clay	19.22
Total	99.74

Fineness, 137; Specific gravity, 2.66; Porosity, 43.43.

Rockton.—A small pit has been opened on the top of a knoll at the south edge of town, and shows two beds, which are sharply separated from each other, and each averaging about five feet in thickness. The lower bed is the finer of the two as well as the more calcareous, which leads to the inference that the upper one may have had much of the lime leached out of it, and also have lost some of its clayey matter by percolating surface water. The top bed is used for medium and heavy casting and the bottom for light gray molding. The mechanical analysis of the two yielded.

Mesh.	Top bed. (Lab. No. 27.) Per cent. retained.	Bottom bed. (Lab. No. 31.) Per cent. retained.
20	0.00	0.00
40	1.12	.90
60	10.68	2.30
80	1.86	.70
100	6.82	1 84
100+	46.38	74 02
Clay	32.86	19.50
Total	99.72	99.26
Fineness	134	129
Sp. grav	2.56	2.67
Porosity	42.09	43.58

Partial chemical analysis.

Silica (SiO_2)	79.41	57.63
Alumina (Al_2O_3)	12.47	10.03
Ferric oxide (Fe_2O_3)	.80	.88
Lime (CaO)	.99	11.16
Magnesia (MgO)	.81	5.63
Ignition	3.96	14.66

These sands are shipped to a number of Wisconsin foundries.

Indiana.

A number of the finer grades sand are dug in this state and shipped to various points including Wisconsin. Their properties are therefore of interest. Those examined were the following:

1. Dye's special (Lab. No. 53). A high grade, fine, strong and rich-colored sand, used especially for fine malleable brass or gray iron. The mechanical analysis yielded:

Mesh of sieve.	Per cent. retained.
20	
40	.06
60	.10
80	.04
100	.12
100+	46.98
Clay	52.64
Total	99.94

Fineness, 174; Specific gravity, 2.50; Porosity, 42.45.

2. New Albany, No. 4. This (Lab. No. 52) is claimed to be a more open fine sand than the the preceding, and used for malleable brass, gray iron and high grade stove plate. Its mechanical composition was:

Mesh of sieve.	Percent retained.
20	
40	.10
60	.20
80	.10
100	.24
100+	76.60
Clay	22.80
Total	99.94

Fineness, 139; Specific gravity, 2.66; Porosity, 41.31.

3. Indiana No. 1. This is a strong red loam sand (Lab. No. 49) of medium texture and the following mechanical composition:

Size of mesh.	Percent retained.
20	.04
40	.66
60	11.42
80	8.12
100	20.64
100+	35.40
Clay	23.42
Total	99.70

Fineness, 105; Specifiic gravity, 2.59; Porosity, 45.18.

4. Indiana No. 2. A red machinery sand (Lab. No. 48) of slightly coarser texture than 3, of the following mechanical composition:

Size of mesh.	Per cent. retained.
20	
40	.94
60	18.18
80	8.54
100	29.96
100+	34.22
Clay	7.91
Total	99.78

Fineness, 88; Specific gravity, 2.62; Porosity, 38.00.

4. Indiana No. 3 (Lab. No. 47). This is a sand of medium texture for light machinery and malleable iron. Its mechanical analysis gave:

Size of mesh.	Per cent. retained.
20	.06
40	.62
60	18.76
80	9.02
100	23.48
100+	33.26
Clay	13.82
Total	99.02

Fineness, 92; Specific gravity, 2.60; Porosity, 42.63.

5. *Valparaiso,* a sand mined by the Garden City Sand Co. of Chicago, is known in the trade as Wanatah sand (Lab. No. 56). This is used for various classes of medium and heavy work, where large cores are used, such as large pipe, fittings and structural iron castings, etc. It is claimed to have high permeability. A mechanical analysis gave:

Mesh.	Per cent retained.
20	.26
40	3.56
60	26.08
80	10.06
100	17.70
100+	15.10
Clay	27.12
Total	99.98

Fineness, 83; Specific gravity, 2.51; Porosity, 43.70.

Kentucky.

Several important grades are obtained from the neighborhood of Newport, Ky. Among these the following may be mentioned.

Newport No. 3 (Lab. No. 45). A light yellow open sand, for light machinery and malleable castings.

Mechanical analysis:

Size of mesh.	Per cent. retained.
20	....
40	.06
60	.84
80	1.00
100	18.32
100+	43.56
Clay	35.52
Total	99.30

Fineness, 137; Specific gravity, 2.61; Porosity, 43.09.

Newport No. 6 (Lab. No. 44). This is a very fine sand, used for light stove plate and brass. Its mechanical analysis gave:

Size of mesh.	Per cent. retained.
20	....
40	....
60	.06
80	.06
100	.62
100+	87.02
Clay	11.92
Total	99.68

Fineness, 132; Specific gravity, 2.64; Porosity, 43.26.

Newport No. 5 (Lab. No. 43). This is also classed as a fine stove plate, and brass sand, but one which is claimed to be stronger than the preceding. This is evidently due to its higher clay content, as shown by the following mechanical analysis:

Size of mesh.	Per cent. retained.
20	
40	.02
60	.04
80	.02
100	.14
100+	77 54
Clay	22.12
Total	99.88

Fineness, 140; Specific gravity, 2.60; Porosity, 40.11.

Michigan.

Only one sand was tested from this state. This is known as the St. James molding sand, and is obtained from the banks of the St. Joe River, St. Joe Co., Michigan (Lab.. No. 51). It is a medium grade sand, used in the manufacture of small gears, medium weight malleable iron and heavy brass, car journals, etc. The mechanical analysis yielded:

Size of mesh.	Per cent retained.
20	
40	.54
60	11.68
80	2.78
100	16.58
100+	43.42
Clay	24.52
Total	99.52

Fineness, 110; Specific gravity, 2.59; Porosity, 46.45.

Minnesota.

The only sand shipped into Wisconsin from this state, so far as known is a red sand (Lab. No. 40) from Kerrick, 20 miles west of Superior. This is used for molding in green-sand casting. It is also used as a binder in conjunction with the sharp lake sand of Superior, in loam molding and in dry sand cores. It is regarded as a very good sand for general heavy work. The mechanical analysis yielded:

Size of mesh.	Per cent retained.
20	6.00
40	8 20
60	19.96
80	6.92
100	16.04
100+	31.72
Clay	10.30
Total	99.14

Fineness, 49; Specific gravity, 2.65; Porosity, 33.91.

Ohio.

Several grades of Ohio molding sand are shipped into Wisconsin from Ohio, most of them coming from the region of Zanesville. One of the finest grades (Lab. No- 16) obtained from the Zanesville region and used for stove plate, has the following mechanical composition:

Size of mesh.	Percent retained.
20	....
40	.16
60	.34
80	.12
100	.18
100+	74.82
Clay	24.16
Total	99.78

Fineness, 140.

In addition to this coarser sands for both light and heavy sands are obtained from the same area.

A type obtained from Massillon, O. (Lab. No. 6), is used by some of the Milwaukee foundries for heavy castings· It has the following composition:

Size of mesh.	Per cent. retained.
20	3.40
40	1.36
60	11.52
80	11.98
100	39.16
100+	24.66
Clay	7.50
Total	99.58

Fineness, 74; Specific gravity, 2.58; Porosity, 42.79.

Still a third type is known as B. Y. No. 1 molding sand (Lab. No. 57) and is obtained from Hamilton Co., Ohio. This is a very fine grained sand. It is used by stove and agricultural machinery manufacturers and casters of ornamental brass. The following mechanical analysis shows it to be the finest grained of the series examined. It was:

Size of mesh.	Per cent. retained.
20	....
40	.10
60	.18
80	.06
100	.12
100+	77.50
Clay	22.40
Total	100.36

Fineness, 139; Specific gravity, 2.59; Porosity, 42.66.

DETAILED ACCOUNT OF WISCONSIN MOLDING SANDS EXAMINED.

Altoona, Eau Claire Co.—A loamy sand (Lab. No. 21) is found on the farm of C. E. Hazen, two miles from Eau Claire. The material underlies the soil, and ranges from 8 in. to 4 feet in thickness. Beneath it there is usually a deposit of coarse sand which is said to be valueless. The sand is moderately fine grained and is used for heavy saw mill castings, sleigh shoes, repair castings, and sash weights. For all except the last, seacoal facing is used. The mechanical analysis yielded:

Size of mesh.	Per cent retained.
20	.44
40	2.82
60	5.76
80	1.44
100	2.86
100+	51.96
Clay	34.46
Total	99.74

Fineness, 119; Specific gravity, 2.67; Porosity, 46.83.

In addition to this occurrence, sand is also dug by William Crandall for use in the local foundries. Dr. Kendall also produces sand for making gray iron castings, and heavy sand for large work. It has to be faced with sea coal.

Beloit, Rock Co.

Molding sand is obtained from the pits of W. V. Whitefield, and used with sea coal for medium to coarse machinery casting; also from the pit of S. Mackie, for similar uses. No analyses were made of this.

Berlin, Green Lake County.—This is probably the most important molding sand producing locality in the state. The output comes from a number of pits, most of which are located about 4 miles southeast of Berlin. In digging the sands it is customary to remove about 6 inches of silty soil, under which the molding sand is found. Two grades are sometimes found in the same pit, or again each pit may yield only one kind. Some idea of the variation may be obtained from the following mechanical analyses:

Size of mesh.	1	7	19	24	28
20	.1	....	....	....	....
40	3.26	.36	1.76	1.46	.54
60	23.82	6.56	10.44	9.78	8.50
80	8.32	3.52	4.50	3.52	5.34
100	26.04	21.22	14.52	14.86	19.14
100+	37.32	64.84	45.42	47.48	60.64
Clay	1.02	2.56	22.64	22.86	4.80
Total	99.88	99.08	99.28	99.96	98.96
Fineness	83.	105.	106.	103.	103.
Specific gravity	....	....	....	2.57	2.60
Porosity	....	....	42.38	43.20	39.4

1. A fine core sand used at Milwaukee.
7. A fine moulding sand used at Milwaukee.
19. No. 3 from White and Traugott's pit.
24. Berlin.
28. No. 2 from White and Traugott's pit.

An attempt was made to ascertain the exact uses to which each kind was put, but in this some difficulty was experienced. Some idea of this may be gained, however, from the following:

The No. 1 grades are used for floor castings ranging from 10 to 1,000 pounds; No. 2, for light work, railway and heavy implements, sea coal facing being required; No. 3, for medium weight castings, thimble skins, bolster plates, reach plates, etc. A few of the coarser grades are also used for cores. The shippers of sand at Berlin are: Berlin Sand Co., James Ferguson, White & Traugott, T. W. Wendt, S. Wilcox & Co., W. Michaels, T. Michaels, and H. S. Spencer.

Burlington, Racine County.

Much sand is dug here by J. Walsh & Son and shipped to Milwaukee and other localities. The sand is mostly of coarse texture, and used for both molds and cores. No analysis was made of it.

Evansville, Rock Co.

Core sand is dug for local use on the property of W. Blakely. It is used in windmill castings, while a medium texture sand for molds for the same class of work is obtained on the property of W. H. Hatfield.

Fairwater, Fond du Lac Co.

Molding sand is dug on the property of John Riemer, in section, 31, N. W. ¼ of S. W. ¼, or about 2½ mi. from Fairwater.

The bank is about 20 feet high and underlain by hardpan. The sand is yellow at the top and lower down varies from white to a light buff. Scattered throughout it there are limonite concretions. The deposit is fairly uniform in character, as shown by the following analyses of which No. 12 represents the run of the bank, and No. 11 selected material.

Size of mesh.	11	12
20	....	....
40	4.86	7.76
60	34.46	32.82
80	8.06	7.24
100	29.38	30.06
100+	22.58	21.96
Clay	.16	.32
Total	99.50	100.16
Fineness	66	68
Specific gravity	2.63	2.61
Porosity	33.90	32.00

Both these are to be classed as rather coarse texture sands, falling in fact within the limits of core sands, and are not unlike No. 15 from Klondike, Mo. They appear to be equally siliceous.

Fort Atkinson, Jefferson Co.—A coarse sand for local use is obtained on the property of H. H. Curtis. This cannot be used without sea coal.

Green Bay, Brown Co.—A medium texture sand for general work is dug on the property of H. W. Woodruff.

Janesville, Rock Co.—The sands obtained around Janesville are mostly adapted to heavy work and cores. The three following samples illustrate well their general characters:

Size of mesh.	30	41	25
20	.4	1.66	....
40	16.54	7.70	4.00
60	56.24	25.20	28.72
80	5.60	8.12	8.48
100	5.20	17.68	22.54
100+	2.60	21.42	21.22
Clay	13.34	18.20	14.84
Total	99.92	100.04	99.82
Fineness	40	70	78
Specific gravity	2.58	2.73	....
Porosity	40.41	32.91	....

30. Sand for cores and heavy work.
41. Sand for heavy work.
25. Core sand. Miltmore quarry.

Kenosha, Kenosha Co.—Molding sand for local use is dug on the property of Chris. Bruns. It is mixed with Illinois and Indiana sands, and in addition requires facing with sea coal. This mixture is then used for castings weighing from 2 up to 60 pounds.

A sand known as the Silverton sand, and obtained in Kenosha county, is used in the manufacture of heavy machinery castings up to the heaviest shapes that are cast in green sand; also large wheels, pulleys, and engine beds. The mechanical analysis of this sand (Lab. No. 50) gave:

Size of mesh.	Per cent. retained.
20	1.32
40	14.02
60	28.68
80	5.62
100	10.24
100+	14.12
Clay	24.02
Total	99.02

Fineness, 63; Specific gravity, 2.55; Porosity, 39.52.

La Crosse, La Crosse Co.—Much sand, usually of coarse character is found underlying the rounded hills, which lie between the Mississippi Bluffs and the river. At some points this is sufficiently clayey for brick making, at others it forms a loamy sand of the proper quality for molding. Such a sand (Lab. No. 23) is much used locally and has the following composition:

Size of mesh.	Per cent. retained.
20	.54
40	7.72
60	13.00
80	1.94
100	8.34
100+	49.76
Clay	18.10
Total	99.40

Fineness, 86; Specific gravity, 2.65; Porosity, 40.37.

The sand varies somewhat even in the same pit. For core work a disintegrated sandstone is obtained in this vicinity.

Madison, Dane Co—Molding sand (Lab. No. 39) of somewhat coarse character is found on Dead Lake Ridge, on the Keyes property, and shipped into town for local use. Its coarse character is well shown by the high percentage retained on the 40 and 60 mesh as shown below:

Size of mesh.	Per cent. retained.
20	10.66
40	21.98
60	43.82
86	6.50
100	9.02
100+	4.12
Clay	3.66
Total	99.76
Fineness	39

The finer sands used by Madison foundries are obtained mostly from Berlin.

Marinette, Marinette Co.—A molding sand deposit is located 2 miles north of Marinette, on the west side of the river. Most of the sand beds in this region are of dune character, but as such sand has no binder, it cannot be used for molding purposes. The local foundry does not use the Marinette sand, but gets its supply from Michigan. The sample (Lab. No. 37) represents run of bank of the Marinette sand.

Size of mesh.	Per cent. retained.
20	2.08
40	3.68
60	12.06
80	4.26
100	9.22
100+	39.14
Clay	29.10
Total	99.54

Fineness, 92; Specific gravity, 2.50; Porosity, 39.18.

Menomonie, Dunn Co.—Underlying the surface in this region, as well as at many points to the west and southwest, there is a fine sandy loam, which is well worthy of investigation for molding purposes. This material, which is known as loess is at times somewhat clayey, at others more sandy, but always fine grained. At Menomonie it is well exposed in the pit of the Menomonie Hydraulic Pressed Brick Co., No. 3 yard, where it is used as part of the brick mixture. The material (Lab. No. 36) has the following mechanical composition:

Size of mesh.	Per cent. retained.
20	.54
40	2.74
60	5.44
80	.82
100	3.74
100+	76.86
Clay	9.16
Total	99.30

Fineness, 106; Specific gravity, 2.63; Porosity, 44.95.

Milwaukee, Milwaukee Co.—This is the great foundry center of Wisconsin, for the number of these establishments located here is not only very great, but some of the individual works like those of the Allis-Chalmers Co., are very large. While these foundries in the aggregate consume a vast amount of molding sand, most of it is obtained from other parts of Wisconsin, and and even other states. Indeed it is but natural that a number of different grades should be called for, when we consider the variety of wares cast at the Milwaukee foundries.

Much sand, however, is obtained from pits near the lake shore, which supply a coarse grade of material suitable for cores or large castings. The producers include C. Beck & Co., W. Grobschmidt, W. Gutknecht, Whitnall & Rademaker, H. Wilhelm, G. Lund, Milwaukee Sand & Gravel Co., L. Natzen, H. Obert, W. Pekel, and A. J. Reiske. Mechanical analyses were made of two of these:

I. A core sand from South Milwaukee, which indicates their coarseness.

II. Core sand from the pit of the Milwaukee Sand & Gravel Co.:

Size of mesh.	I.	II.
20	6.90	3.56
40	11.44	5.47
60	27.76	28.41
80	8.76	10.61
100	14.10	27.76
100+	12.47	22.75
Clay	18.52	tr.
Total	99.95	98.55
Fineness	54	62
Sp. grav	2.61	2.64
Porosity	38.83	37.47

Neenah, Winnebago Co.—There are several producers of molding sand in this vicinity, whose names, together with the known uses of the sands produced are as follows:

F. Covert—Sand for general grade of machine casting, faced with sea coal.

Gilbert Jones—Fine sand for light casting.

Neenah Sand Bank Co.—Sand for general work.

R. Pendleton—Sands ranging from coarse to fine, and used for corresponding grades of work. The finest is classed as brass sand.

These Neenah sands while used locally are also shipped to many parts of the state.

The following analyses will give some idea of the character of the sands obtained in this vicinity.

Size of mesh.	Lab. No. 26	Lab. No. 34	Lab. No. 35
20			
40	2.02	.56	1.26
60	20.78	1.8	4.26
80	7.32	2.12	1.40
100	15.96	1.00	5.64
100	38.7038.70	61.74	52.04
Clay	14.54	30.66	35.14
Total	99.32	99.88	99.74
Fineness	90	121	131
Specific gravity	2.61	2.67	2.59
Porosity	44.76	44.07	44.62

No. 26, Collins pit, Neenah.
No. 34, Brass sand. Pendleton pit.
No. 35, Medium sand, same pit.

No. 26, Collin's pit, Neenah.
No. 34, Brass sand, Pendleton pit.
No. 35, Medium sand, same pit.

Pardeeville, Columbia County.—Molding sand is dug on the Charmely property ¼ mile north of the station and along the railroad track. This sand is a medium to a coarse sand, used for general work, and the three following analyses are interesting as showing the variation that may occur in the same bank. Nos. 4 and 5 are average samples taken at different times, and representing the run of the bank, while No. 10 is a selected sample.

Size of mesh.	4	5	10
20		1.80	
40	.36	9.08	5.92
60	23.76	35.68	42.00
80	9.50	7.94	11.64
100	35.76	13.90	22.58
100+	30.22	19.78	12.76
Clay	.36	11.04	5.06
Total	99.96	99.22	99.06
Fineness	82	62	62

Racine, Racine Co.—This is next to Berlin, the most important molding-sand producing locality in Wisconsin. The sands are obtained near the lake shore chiefly to the north of the city. These deposits consist of vari-textured sands several grades sometimes overlying each other in the same pit. In all cases the upper foot of soil has to be removed before good sand is exposed, and in no case are the excavations extensive or deep.

The sands range from core sands to those of moderately fine grain, but none are as fine as those obtained from Indiana, Kentucky or Ohio.

Three analyses given below, will indicate something of the grades dug near Racine.

No. 29 is a very fine core sand.

No. 32, a fine-grained molding sand, for small castings; No. 33, a coarse sand for heavy castings.

Size of mesh.	29	32	33
20			
40	1.04	.70	.72
60	11.74	3.54	24.68
80	5.80	1.38	11.78
100	28.48	7.22	26.60
100+	46.08	47.46	19.20
Clay	6.60	39.44	16.30
Total	99.74	99.74	99.28
Fineness	86	136	86
Specific gravity	2.60	2.65	2.58
Porosity	37.66	44.4	41.16

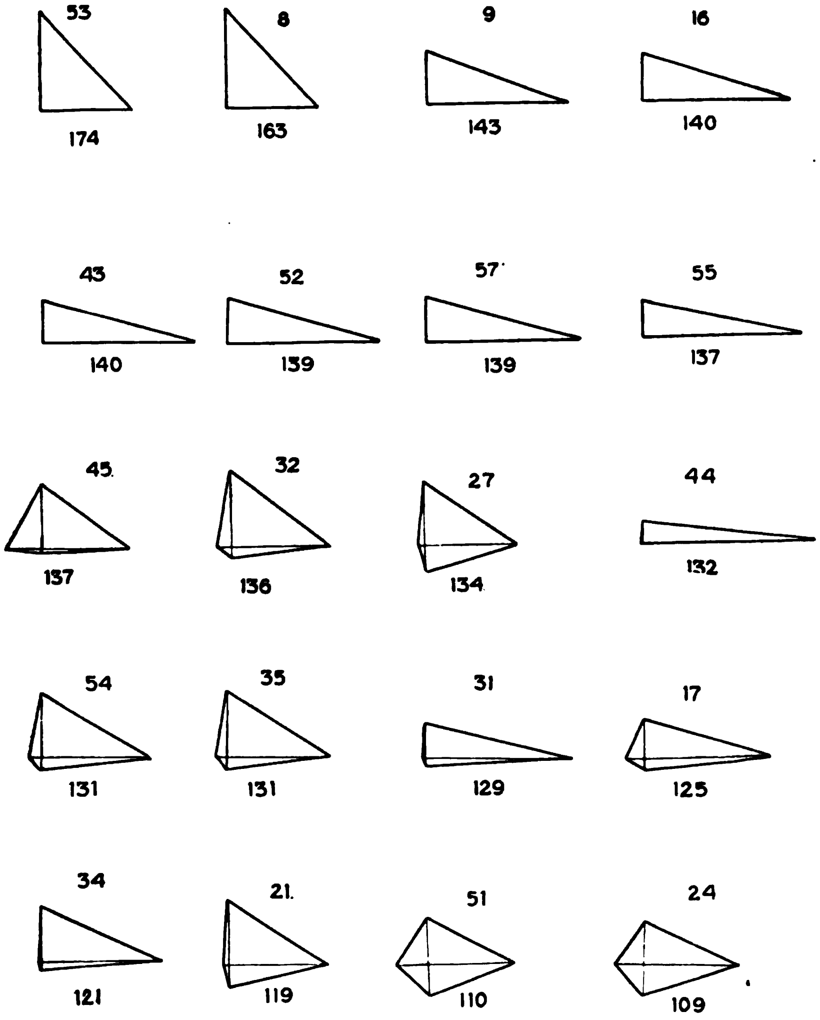
The Racine sands are used for a variety of light and medium work, and are commonly faced with sea coal. Some foundrymen mix them with Illinois and Indiana sands.

Superior, Douglas Co.—A sharp lake sand from Lake Superior is used by U. S. Cast Iron Pipe & Foundry Co., and employed in either loam or dry sand cores. About 50 per cent of it is used in pipe cores in conjunction with the red sand, and some old core sand. It makes very porous cores and lets the gases escape very easily. Its mechanical analysis was:

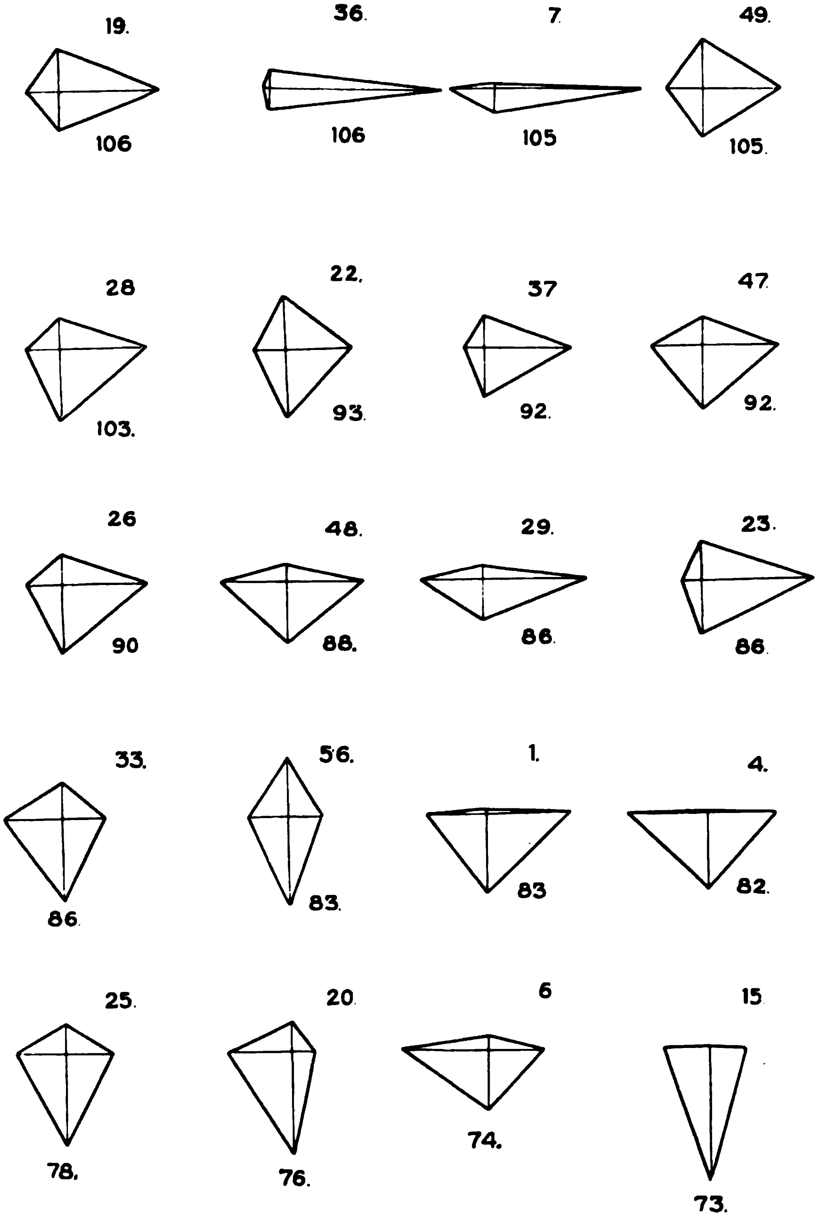
Size of mesh.	Percent retained.
20	12.76
40	35.06
60	40.56
80	5.72
00	3.24
100+	1.54
Clay	.40
Total	99.28

Fineness, 63; Specific gravity, 2.61; Porosity, 32.50.

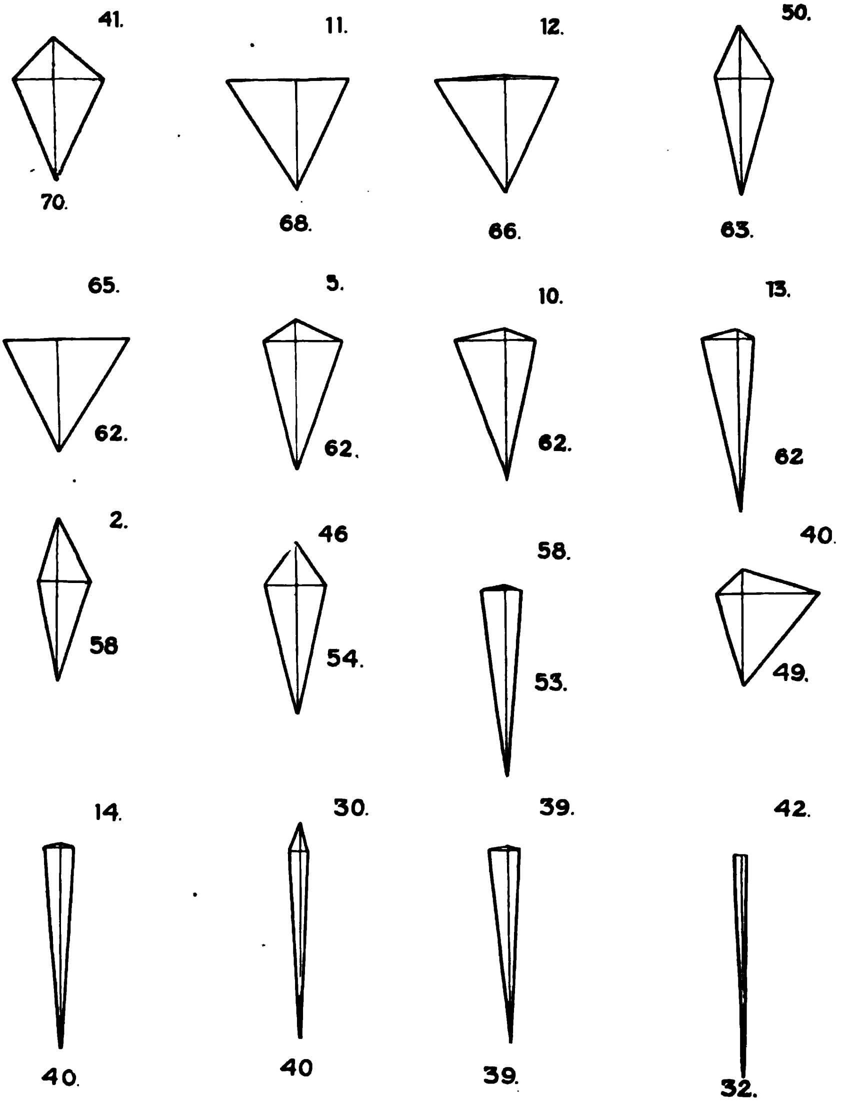
Waukesha, Waukesha Co.—G. S. Atkinson, supplies a core sand to the Waukesha Malleable Iron Co., of Waukesha, as reported by them.



Graphic representation of mechanical composition of molding sands. The upper number is the laboratory number, and the lower one the average fineness.



Continuation of series shown on Pl. XXVIII.



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